



Carbon Sequestration in Harvested Wood Products (HWP)

Data for 2013-Reporting to the UNFCCC, Final Draft

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Executive summary

Carbon emissions from harvested wood products (HWP) must now be accounted for by parties under the Kyoto Protocol linked to the United Nations Framework Convention on Climate Change (UNFCCC) for the second commitment period (2013-2020). This report explains the basis of the Danish reporting of HWP for 2013.

Carbon in the HWP pool is accounted for based on the semi-finished wood product categories: *sawnwood*, *wood-based panels* and *paper and paper products* with default half-lives of 35, 25 and 2 years, respectively, stipulated by the Intergovernmental Panel on Climate Change (IPCC). HWP originating from imported wood must be excluded from the accounting. HWP originating from deforestation activities must be accounted for on the basis of instantaneous oxidation.

For calculating carbon stocks in HWP, Denmark has applied the default first order decay (FOD) model stipulated by the IPCC, with the default half-lives (IPCC Tier 2 methodology). Activity data has been collected from international databases as well as from surveying the Danish wood industry (IPCC Tier 2 and 3 methodologies). Carbon conversion factors have been derived from national forest inventory data (IPCC Tier 3 methodology).

An extensive validation of activity data was carried out leading to corrections of historic data, especially regarding the production and export of sawnwood. In this process a questionnaire was sent out to the Danish wood industry in June 2014. The objective was to obtain production figures for sawnwood and wood-based panels for the years 2011, 2012 and 2013 in order to provide accurate estimates for the most recent inflow to the HWP pool and to assist the validation of historic data.

For the accounting of emissions a *Forest Management Reference Level* (FMRL) is constructed specifying the expected average annual net emissions - including those from the HWP pool - for the second commitment period. Due to the data corrections it was decided to correct the original FMRL reported in 2011. This correction also entailed a change in the reference period used to project the inflow to the HWP pool – from 2005-2009 to 2008-2012 – in order to provide a more accurate reference level using the most recently collected data. Had the reference period not been changed, the FMRL would have significantly underestimated the inflow for 2013 and thus caused a significant gap between the reported net emissions and the projected net emissions by the FMRL. This means that the HWP pool would actually have been projected to decrease as opposed to the expected increase in the pool during the second commitment period.

According to the Questionnaire on the production of the Danish wood industry the production of sawnwood in 2013 was about 356.000 m³, while the production of wood-based panels was about 346.000 m³. The Questionnaire covered an estimated 95% of the revenue generated in the sawnwood sector and 100% of the sector revenue for wood-based panels (there was only 1 relevant company). A cross validation of the roundwood consumption showed an average deviation of 8% for 2011-2013 between the Questionnaire and the figures reported by Statistics Denmark based on harvest and trade statistics.

As of 2013 the HWP pool originating from domestic harvest and domestic consumption consisted of about 5 Mio. ton carbon (67% from sawnwood and 33% from wood-based panels – the paper pool was insignificant). This is equivalent to 13% of the carbon stock in live forest biomass. If imported wood were

also included, the pool increases to about 29 Mio. ton carbon equivalent to 75% of the carbon stock in live forest biomass. The total inflow of carbon to the HWP pool in 2013 is reported to about 144.000 ton carbon - 63.000 ton from sawnwood and 81.000 ton from wood-based panels. The outflow from the pool is reported to about 110.000 ton carbon in 2013 - 65.000 ton from sawnwood and 45.000 ton carbon from wood-based panels. Thus there has been a net carbon sequestration in HWP of about 34.000 ton carbon in 2013. This corresponds to 0,13% of Denmark's total CO₂-emissions for 2012.

The corrected FMRL has projected the inflow in 2013 to about 132.000 ton carbon (61.000 ton from sawnwood and 71.000 ton from wood-based panels) and the outflow to about 110.000 ton carbon in 2013 (65.000 ton from sawnwood and 45.000 ton from wood-based panels). The projected net sequestration is about 22.000 ton carbon. For the entire second commitment period the corrected FMRL projects a HWP contribution of an average annual net emission of $\pm 0,065$ Mio. ton CO₂ equivalents/year. I.e. the HWP pool is projected to increase over the period.

The uncertainty on the HWP estimates should be noted. The estimate of the size of the total HWP stock is quite uncertain, as the empirical basis for the FOD model and the attached half-lives is weak. Conducting direct inventories of the carbon stock may be a method to reduce uncertainty. In the case of Denmark estimates based on the FOD model for the total HWP pool including imported wood and converted to finished wood products actually came quite close, when measured per capita, to estimates from Finland originating from a direct inventory. Regarding estimates for pool changes, uncertainty on half-life may be of less importance, as longer retention time in the pool may be traded off against higher emissions levels from the historic pool. This depends on the characteristics of the pool, i.e. the size of the pool vs. the recent inflow. Uncertainty on activity data relates both to uncertainty on measurements, e.g. caused by reporting errors, and statistical uncertainty, caused by variation in the sampled population.

The reported net carbon sequestration for 2013 is relatively close to the corrected FMRL, and the same is expected for the remainder of the second commitment period. Judging from the coverage and the validation results, surveying the production of semi-finished wood products in Denmark by questionnaire has been successful. It will be repeated in the following years as part of the future reporting of HWP. Besides giving a better basis for the reporting to the UNFCCC, the Questionnaire provides a valuable insight into the wood industry and the wood flows in general.

Preface

This report has been prepared in relation to the Danish reporting of carbon in harvested wood products (HWP) for 2013 under the Kyoto Protocol, which is linked to the United Nations Framework Convention on Climate Change (UNFCCC). HWP is included in the section of the Kyoto Protocol dealing with landuse, landuse change and forestry (LULUCF) under articles 3.3 and 3.4. The report preparation has been carried out by the Department of Geosciences and Natural Resource Management (IGN) at the University of Copenhagen on behalf of the Danish Energy Agency (Danish Ministry of Climate, Energy and Building).

In order to secure a proper reporting for the second commitment period of the Kyoto Protocol (2013-2020) the Danish Energy Agency initiated several projects all aiming at enhancing knowledge and collecting data for the documentation of carbon emissions/sequestration (SINKS 2). Among these a specific project was assigned to deal with the reporting of HWP: "Development of methods and routines for collection of validated data for the use of estimating the amount of stored carbon in harvested wood products (HWP-data)". The present report documents the work carried out under this project.

It was acknowledged, that there was a need for collecting data regarding the production of sawnwood and wood-based panels (semi-finished wood products) additional to the data reported to the Food and Agricultural Organization of the United Nations (FAO). Consequently a questionnaire was formulated and sent out to the Danish wood industry. After the collection of data on production, import and export an extensive data validation process took place. The objective was to deliver the best possible estimates on annual production, import and export of sawnwood and wood-based panels with increased emphasis on recent years, as those have a higher importance for the estimation of present emissions. In the process a mapping of the collective wood flows in Denmark was also initiated - this work is still ongoing, but is referred to in the report.

The project has been supported by a steering committee consisting of representatives from the Danish Nature Agency (Danish Ministry of Environment), Statistics Denmark, the Danish Wood and Furniture Industry, the Danish Forest Association, the Danish Energy Agency (Ministry of Climate, Energy and Building), the Danish Centres of Building and the Department of Geosciences and Natural Resource Management (University of Copenhagen). A total of five meetings involving the project staff and the steering committee have been conducted through 2014 and early 2015.

Frederiksberg, 28/02/2015

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Abbreviations

AR	= Afforestation/Reforestation
C	= Carbon
CMP	= Conference of the Parties serving as meeting of the Parties
COP	= Conference of the Parties
D	= Deforestation
FAO	= Food and Agricultural Organization of the United Nations
FM	= Forest Management
FMRL	= Forest Management Reference Level
FOD	= First order decay
FWP	= Finished wood products
HWP	= Harvested wood products
IPCC	= Intergovernmental Panel on Climate Change
IRW	= Industrial roundwood
JFSQ	= Joint Forest Sector Questionnaire
KP	= Kyoto Protocol
NFI	= National Forest Inventory
SFWP	= Semi finished wood products
SD	= Statistics Denmark
UNFCCC	= United Nations Framework Convention on Climate Change

1 Introduction

1.1 The background of HWP reporting under the Kyoto Protocol

In 1998 Denmark signed the Kyoto Protocol (KP), which stipulates internationally binding reduction targets regarding the emissions of greenhouse gases (UNFCCC, 2014). As carbondioxide (CO₂) is an important greenhouse gas, parties must keep track of the national flow of carbon in order to account for emissions (/sequestration) of CO₂. Denmark has elected accounting on an annual basis.

At the 17th conference of the parties (COP17) to the UNFCCC in Durban it was decided that emissions from HWP should be accounted for from 2013 onwards (UNFCCC, 2012).

The following terms were agreed upon through Decision2/CMP.7¹:

- Imported HWP should not be accounted for.
- Definition of default half-lives (mean life times) for the HWP categories: Sawnwood, wood-based panels and paper.
- HWP originating from deforestation should be accounted for on the basis of instantaneous oxidation.
- Rejected HWP in solid waste disposals and HWP used for energy production should be accounted for on the basis of instantaneous oxidation.
- Each country using a projected forest management reference level could decide upon whether or not to include HWP produced prior to the start of the second commitment period (2013-2020).
- Accounting for HWP originating from afforestation and reforestation under article 3.3 and from forest management under article 3.4 should be treated separately.

1.1.1 Accounting of emissions - Forest Management Reference Level

For the accounting of emissions a Forest Management Reference Level (FMRL) is constructed according to Decision 2, CMP.7 – paragraph 16 (UNFCCC, 2012). The FMRL specifies the expected average annual net emissions (emissions ÷ sequestration) originating from forest management (FM) for the second commitment period. The actual (reported) annual net emissions for the period will then be compared to the FMRL (IPCC, 2014 – page 2.93). FM under article 3.4 is defined as taking place in areas with forests which also contained forests on 31. December 1989 and thus do not qualify for afforestation and reforestation under article 3.3, and is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner (Decision 16/CMP.1 (UNFCCC, 2006) and Decision 2/CMP.6 (UNFCCC, 2011)). The methodology of the construction of the FMRL is treated in Sections 2.3.3 and 2.4.2.1.1.

The FMRL may be described by a “business as usual” scenario, where the emissions are forecasted on the basis of the expected harvest level in the commitment period. The HWP contribution to the original FMRL reported in 2011 was calculated with a baseline period from 2005-2009, which at that time was the five most recent years, where relevant data was available (Johannsen et al., 2011).

¹ Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol on its seventh session

It was decided, that due to major changes in the data material used in the annual HWP reporting a revision of the original FMRL is needed, aligning the data used to calculate the FMRL to that used in the reporting. This is referred to as a technical correction – a value which should be added to the FMRL at the time of accounting. The revision of FMRL also includes a change in the reference period. It was decided to change the reference period from 2005-2009 to 2008-2012, in order to provide a more accurate FMRL using the most recent data. As will be evident from Section 3.2.4 this ensures against a significant underestimation of the inflow to the HWP pool by the FMRL.

1.2 Description of HWP

1.2.1 Description of the HWP pool

Products flow into the common pool of HWP in use from the domestic wood industry and from imported wood. After a certain period of use, they leave the pool as discarded products. Only semi-finished wood products (SFWP), i.e. sawnwood, wood-based panels and paper, are accounted for. Thus finished products (e.g. furniture, floors, beams, books etc.) do not enter in the estimations.

In order to estimate the changes in the HWP pool the inflow and outflow from the pool must be known. The inflow can be estimated directly from data on the production of HWP. The outflow from the pool may only be determined directly based on successive inventories of products in use – this is quite resource demanding and requires an extensive data material. In the case of Denmark no such inventories have been made. However the outflow may be estimated based on a theoretical model put forward by the Intergovernmental Panel on Climate Change (IPCC) - its use is stipulated in Decision 2/CMP.7. This model estimates the outflow from the pool based on the size of the pool and the product life expectancies (half-lives). Currently the empirical foundation of the model setup is quite weak, but it will quite likely be improved, as the reporting of HWP is carried out through the second commitment period. This model constitutes the theoretical basis of the estimations of the changes in the HWP pool for Denmark.

1.2.2 Inflow

Decision 2/CMP.7 stipulates that only HWP produced and consumed domestically may be included in the HWP pool of the reporting country. I.e. the HWP-carbon must originate from trees harvested and used in the reporting country². This means that the domestic production must be divided into two parts: One part produced from domestically harvested wood, and one part produced from imported roundwood. Furthermore the share produced from domestically harvested wood must be divided into domestically used HWP and exported HWP, as it is only the former that may be accounted for.

Because of the huge amount of data involved in the estimation, there are many potential sources of errors that may influence the final result. Even small errors in the data can lead to significant errors in the result, especially if subtraction operations are performed on the data, which is the case, when estimating the net inflow to the HWP pool.

1.2.3 Outflow

The choice of expected life times for the HWP products influence the size of the stock and thus the stock changes. However the influence on the stock changes may be relatively small (depending on the pool

²Note that this means wood from Danish forests used by mills and industries in Denmark.

characteristics), as the applied lifetimes influence both the size of the stock and the size of the outflow - and as these two are opposing effects they may cancel out each other.

1.2.4 The stock change

Because the stock change is calculated by subtracting inflow from outflow even small errors in the inflow and/or outflow data may result in significant errors in the stock change. The problem is common to all countries, but the Danish accounting is highly sensitive, because Denmark has a small production of HWP combined with a large international trade. Thus the stock change constitutes a small proportion of the inflow and outflow.

The uncertainty on the HWP estimations is treated in Section 3.4.

2 Methods and Materials

2.1 Choice of guidelines for reporting HWP

Presently two set of guidelines for estimating the carbon stock in the HWP pool exist. The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (2006 IPCC Guidelines) (IPCC, 2006) and the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (2013 KP Supplement) (IPCC, 2014). In the latter it is specifically stated that it is “...consistent with the 2006 IPCC Guidelines but does not revise or replace the 2006 IPCC Guidelines” (IPCC, 2014 – page 2.109). I.e. currently the two set of guidelines are in theory equally valid. However Decision 2/CMP.7 (UNFCCC, 2012) has imposed additional restrictions on the reporting in comparison with 2006 IPCC Guidelines. The 2013 KP Supplement is developed in accordance with Decision 2/CMP.7 (and 2/CMP.8 – UNFCCC, 2012), and as *it is the latest set of guidelines, this reporting has been prepared on the basis of the 2013 KP Supplement*. Only when this guideline refers specifically to methods employed by the 2006 IPCC Guidelines have these been used. For comparison, some results are prepared using both sets of guidelines.

2.2 Definitions

For clarity this section outlines the definition of some key terms used in the reporting in accordance with the 2013 KP supplement and the Joint Forest Sector Questionnaire (JFSQ) (FAO et al., 2014).

The term “roundwood” is used to define *wood in the rough* – i.e. all roundwood, independent of the further use. “Industrial roundwood” is defined as roundwood used for production of sawnwood, wood-based panels and paper – but not fuelwood (firewood and wood chips). Industrial roundwood encompasses timber and lumber defined as wood for sawmilling, pallet wood defined as wood for the production of pallets, pulpwood defined as wood for the production of pulp for paper production and other industrial roundwood for other purposes. “Sawnwood” is defined as the product resulting from the sawing of roundwood (e.g. sawn timber and boards), while “wood-based panels” is an aggregate category of products resulting from the processing of shredded roundwood or residual wood materials (e.g. particleboards). The term “conifer” defines coniferous species, while “non-conifer” defines species, which are not conifers – in this report it is considered analogue to broadleaved species.

2.3 General description of reporting of HWP

The estimation of carbon in the HWP pool is based on the three semi-finished wood product categories: (1) sawnwood, (2) wood-based panels, and (3) paper and paperboard (also referred to as HWP categories) – see 2013 KP Supplement (IPCC, 2014).

2.3.1 Tiers

Three tiers of methods may be used when calculating carbon stocks in HWP according to the 2013 KP supplement (IPCC, 2014):

- *Tier 1:* This method assumes that the HWP carbon stock is constant over time, i.e. that the inflow to the pool equals the outflow from the pool. This is equivalent to assuming instantaneous oxidation of HWP resulting in zero annual net-emissions from the pool, as the annual stock change is zero.
- *Tier 2:* This method employs standard (default) IPCC models/parameters and standard activity data from international databases (e.g. data from FAO-STAT) to estimate the HWP carbon stock. The method may be used “provided that verifiable and transparent activity data are available” (IPCC, 2014 – page 2.119).
- *Tier 3:* This method employs country specific methods and country specific activity data. As for Tier 3 activity data must be verifiable and transparent and methodologies must be “at least as detailed and accurate” as for Tier 2 (IPCC, 2014 – page 2.123)

In this reporting a combination of Tier 2 and 3 methods, as the standard IPCC method for estimating the HWP carbon stock is used in combination with country specific activity data as well as data from international databases.

Comparing with 2006 IPCC Guidelines the definition of tiers have been changed. In these guidelines Tier 1 describes the above mentioned Tier 2 method, while Tier 2 supplements Tier 1 with using country specific data. Finally Tier 3 is the application of country specific methodologies (IPCC, 2006).

2.3.2 Method for calculating carbon stocks in HWP

A first order decay (FOD, i.e. exponential decay) function is used to estimate the carbon stock and the annual changes for each of the SFWP categories in accordance with 2013 KP Supplement Equation 2.8.5 (IPCC, 2014 – page 2.120):

$$C_{i+1} = e^{-k} \times C_i + \left[\frac{1 - e^{-k}}{k} \right] \times Inflow_i$$
$$\Delta C_i = C_{i+1} - C_i \quad (1)$$

Where:

C_i is the carbon stock for the given HWP category at the beginning of year i (variables are written with index i , as the equation is used in the discrete form)

k is the decay constant depending on the HWP category - $k = \ln(2)/T_{1/2}$, where $T_{1/2}$ is the half-life

$Inflow_i$ is the inflow to the given HWP category during year i

ΔC_i is the change in carbon stock during year i .

The calculations start at year 1900 equal to time, $i = 0$, according to the 2006 IPCC Guidelines. This method of estimating the carbon stock in HWP is referred to as the “flux-data method” (cf. IPCC, 2006).

2.3.2.1 Estimation of initial carbon stock – 2006 IPCC vs. 2013 KP Supplement

The use of Equation 2.8.5 depends on the estimation of an initial carbon stock at year $i = 0$. In this respect the two set of guidelines differ. In the 2006 IPCC guidelines the initial stock at year 1900 is set equal to zero, i.e. $C_{t_0} = 0$. In the 2013 KP Supplement the initial stock is estimated by Equation 2.8.6 (IPCC, 2014 – page 2.121):

$$C_{t_0} = \frac{Inflow_{average}}{k} = Inflow_{average} \times \tau$$
$$Inflow_{average} = \frac{\sum_{i=t_0}^{t_4} Inflow_i}{t_4 - t_0} = \frac{\sum_{i=t_0}^{t_4} Inflow_i}{5 \text{ years}} \quad (2)$$

Where:

C_{t_0} is the HWP carbon stock for a given HWP category at year 0

$Inflow_{average}$ is the average inflow over the first 5 years of the considered time period ($t_0 - t_4$)

τ is the mean lifetime depending on the HWP category

Thus the absolute difference in initial stock is quite large between the two set of guidelines. This difference decreases over time, as the initial HWP carbon leaves the pool and is replaced by new inflows to the pool. Results will be provided for both estimation methods. However, *it is the results based on the 2013 KP supplement method that will be used for the reporting (cf. Section 2.1).*

2.3.2.2 Estimation of historic inflow 1900-1961

For Denmark historic data is only available back to 1961. The historic inflow to the HWP pool back to 1900 is estimated by Equation 12.6 from the 2006 IPCC Guidelines (IPCC, 2006 – page 12.18):

$$V_t = V_{1961} \times e^{[U \times (t - 1961)]} \quad (3)$$

Where:

V_t is the annual inflow to the given HWP category at time t

V_{1961} is the annual inflow to the given HWP category in year 1961

U is the estimated continuous rate of change in industrial roundwood consumption for the world region, which the given country belongs to

2.3.2.3 Allocation of HWP to activities

The treatment of HWP depends on the activity of origin. Decision 2/CMP.7 stipulates that HWP originating from deforestation (D) activities must be accounted for on the basis of instantaneous oxidation (this is also the case for HWP in solid waste disposal sites). I.e. only HWP originating from activities classified as Forest Management (FM) and afforestation (AR) may be included in the pool.

HWP originating from deforestation is excluded from the pool by determining the fraction of the feedstock (roundwood for production of HWP) originating from deforestation by 2013 KP Supplement Equation 2.8.3 (IPCC, 2014 – page 2.116):

$$f_{j,i} = \frac{harvest_{j,i}}{harvest_{total,i}} \quad (4)$$

Where:

$f_{j,i}$ is the share of the harvest originating from activity j in year i

$harvest_{j,i}$ is the harvest originating from activity j in year i

$harvest_{total,i}$ is the total harvest from all activities in year i

As no data on harvest originating specifically from afforestation activities exists, it is assumed, in accordance with 2013 KP supplement good practices (IPCC, 2014 – page 2.118), that the contribution to the HWP pool is zero. Anyway taking into account the average age, species composition and growth rates of afforested areas in Denmark the production of industrial roundwood presently, must be expected to be minimal.

On deforestation activities the harvest is estimated from information on the standing volume on deforested lands according to the Danish national forest inventory (NFI – cf. Johannsen et al., 2013), in accordance with 2013 KP supplement good practices (IPCC, 2014 – page 2.117). Standing volume is converted to harvested volume of industrial roundwood by multiplying with factors to correct for the share of merchantable volume and the share of roundwood used for industrial roundwood (an assumed ratio of merchantable to total volume of 0,87 is used).

2.3.2.4 Estimation of share of HWP from domestic harvest

To estimate the share of HWP originating from domestic harvest 2013 KP Supplement Equation 2.8.1 (IPCC, 2014 – page 2.115) is used for the categories sawnwood and wood-based panels:

$$f_{IRW,i} = \frac{IRW_{P,i} - IRW_{EX,i}}{IRW_{P,i} + IRW_{IM,i} - IRW_{EX,i}} \quad (5)$$

Where:

$f_{IRW,i}$ is the ratio of domestically harvested and consumed industrial roundwood (feedstock) to the total domestic consumption of industrial roundwood in year i

$IRW_{P,i}$ is the production of roundwood in year i

$IRW_{IM,i}$ is the import of roundwood in year i

$IRW_{EX,i}$ is the export of roundwood in year i

In this reporting $f_{IRW,i}$ is estimated separately for sawnwood (for conifer and non-conifer) and wood-based panels based on the determined roundwood consumption for each of the categories³.

For paper the estimation is done by multiplying Equation 2.8.1 with 2013 KP Supplement Equation 2.8.2 (cf. IPCC, 2014 – page 2.115):

³ This estimation method does not take into account the origin of the wood scrap wood used in production of wood-based panels. See also Section 2.5.2.3.

$$f_{PULP,i} = \frac{PULP_{P,i} - PULP_{EX,i}}{PULP_{P,i} + PULP_{IM,i} - PULP_{EX,i}} \quad (6)$$

Where:

$f_{PULP,i}$ is the ratio of domestically harvested and consumed pulpwood to the total domestic consumption of pulpwood in year i

$PULP_{P,i}$ is the production of pulpwood in year i

$PULP_{IM,i}$ is the import of pulpwood in year i

$PULP_{EX,i}$ is the export of pulpwood in year i

The ratios from 1900-1960 are assumed constant, in line with section 2.4.1.3, and estimated by the average ratios for 1961-1964.

Thus the amount of HWP domestically harvested and domestically consumed for a given activity j is estimated by Equation 7:

$$HWP_{j,i} = (HWP_{P,i} - HWP_{E,i}) \times f_{DP,i} \times f_{j,i} \quad (7)$$

Where:

$HWP_{j,i}$ is the production of HWP for activity j in year i

$HWP_{P,i}$ is the total production of HWP for activity j in year i

$HWP_{E,i}$ is the total export of HWP for activity j in year i

$f_{DP,i}$ is the share of HWP originating from domestic harvest

$f_{j,i}$ is the share of HWP associated with activity j

2.3.3 Forest Management Reference Level - correction

Since the first reporting of the FMRL new data/corrected data is now available. This necessitates a correction of the HWP contribution to the FMRL (cf. IPCC, 2014 - Table 2.7.1, page 2.101). The estimation of the FMRL and the corrected reference level, $FMRL_{corr}$, is based on a projection representing a “business as usual scenario”. The projected inflow to the HWP pool in the second commitment period 2013-2020 is based on the ratio of the annual projected harvest for the period to the average historic harvest 2008-2012 (IPCC, 2014 – page 2.130):

$$HWP_{projected,i} = HWP_{average\ 2008-2012} \times \frac{Harvest_{projected,i}}{Harvest_{average\ 2008-2012}} \quad (8)$$

Where:

$HWP_{projected,i}$ is the projected production of HWP in year i

$HWP_{average\ 2008-2012}$ is the average historic production of HWP for years 2008-2012

$Harvest_{projected,i}$ is the projected harvest in year i

$Harvest_{average\ 2008-2012}$ is the average historic harvest for years 2008-2012

This method is applied based on the assumption that the production of HWP covariates with the harvest in the forests – and thus that the production of domestic HWP may be forecasted by forecasting the harvest. In general this assumption is quite reasonable, however changes in assortment distribution and export rates will affect the validity of the assumption - e.g. for Denmark the share of fuelwood in the harvest has been increasing. This aspect has not been considered in the current calculation of the FMRL, but it may be included in the future reporting of the FMRL.

The technical correction is calculated by 2013 KP Supplement Equation 2.7.1 (IPCC, 2014 – page 2.98) as:

$$Technical\ Correction = FMRL_{corr} - FMRL \quad (9)$$

Where:

Technical Correction is the correction in terms of the absolute difference between the original FMRL and the corrected FMRL – i.e. the difference in the projected net-emissions from the HWP pool.

Equation 2.7.1 is applied, as only a CMP-decision may change a country's officially reported FMRL. A recalculation alone cannot do this (cf. IPCC, 2014 – page 2.98).

For accounting purposes it is important to note that the calculated FMRL includes emissions from the historic pool of HWP, i.e. emissions from products placed in the pool before the start of the second commitment period (inherited emissions) – this is to ensure consistency with the annual reporting, which also includes inherited emissions. Emissions from the first commitment period are included as instantaneous oxidation under art. 3.3 and 3.4.

2.4 Data

2.4.1 Model parameters

2.4.1.1 Emissions factors - half-life

For applying Equation 2.8.5 IPCC default values on half-lives (Tier 2) are used (IPCC, 2014 – page 2.123):

- Paper = 2 years
- Wood-based panels = 25 years
- Sawnwood = 35 years

2.4.1.2 Carbon conversion factors

For the conversion of wood volume or weight into carbon the following conversion factors, including both IPCC default values (Tier 2) and country-specific values (Tier 3), are used:

- Paper = 0,386 Mg C/Mg (IPCC default)
- Wood-based panels = 0,269 Mg C/m³ (IPCC default)
- Sawnwood, conifer = 0,235 Mg C/m³ (Country-specific)
- Sawnwood, non-con. = 0,286 Mg C/m³ (Country-specific)

To estimate conversion factors for sawnwood, data from the NFI (Nord-Larsen et al., 2014) on live above ground biomass and standing volume of tree species in the forests is used in Equation 10:

$$Density_{C,f} = \frac{Biomass_f \times Prop_C}{Standing\ volume_f} \quad (10)$$

Where:

$Density_{C,f}$ is the carbon density for species f

$Biomass_f$ is the live above ground biomass for species f

$Prop_C$ is the proportions of carbon in the biomass - a value of 0,5 is used.

$Standing\ volume_f$ is the standing volume for species f

As the historic sawnwood production before 2011 is only known on the basis of species groups (conifer and non-conifer), densities are converted to this level by using the average proportion of species in the sawnwood production for 2011-2013 as stated by Equation 11 (see also Section 2.4.2.3):

$$Density_{C,S,k} = \sum_{f=1}^k Density_{C,f} \times Share_{prod\ 2011-2013,f} \quad (11)$$

Where:

$Density_{C,S,k}$ is the carbon density for species group S consisting of k species

$Share_{prod\ 2011-2013,f}$ is the share of the sawnwood production for species f

This is the carbon density of fresh wood. As wood volume decreases under drying this yields a conservative estimate of the carbon content in sawnwood. The estimation is based on carbon density functions developed for Danish conditions for norway spruce (*Picea abies* (L.) Karst.), sitka spruce (*Picea sitchensis* (Bong.) Carr.), silver fir (*Abies alba* Mill.), beech (*Fagus sylvatica* L.), larch (*Larix* sp.), douglas fir (*Pseudotsuga menziesii* Mirb. Franco) and grand fir (*Abies grandis* Dougl. Lindley). For other species the function of the most similar species is applied.

Table 1 and Table 2 show the data on the calculation of the carbon conversion factors.

Table 1. Conversion factors for sawnwood based on volume and biomass estimations from the Danish National Forest Inventory and an assumed carbon fraction of 0,5 based on IPCC (2014).

Species/species group	Total standing volume [1.000 m ³]	Total biomass content [1.000 Mg]	Carbon fraction	Conversion factor [Mg C/m ³]
Beech	33.334	19.924	0,5	0,30
Oak ⁴	12.423	7.149	0,5	0,29
Maple ⁵	6.404	2.599	0,5	0,20
Ash ⁶	5.111	2.888	0,5	0,28
Birch ⁷	4.928	2.626	0,5	0,27
Other broadleaved	9.214	4.441	0,5	0,24
Norway spruce	22.696	10.700	0,5	0,24
Sitka spruce	7.862	3.745	0,5	0,24
Silver fir	5.424	2.599	0,5	0,24
Pine ⁸	8.688	5.369	0,5	0,31
Nordmann fir ⁹	1.379	737	0,5	0,27
Noble fir ¹⁰	1.992	1.018	0,5	0,26
Other conifer	8.733	3.972	0,5	0,23

Table 2. Weighted carbon conversion factors for conifer and non-conifer sawnwood based on species shares in the questionnaire on the production of sawnwood.

Tree species/group	Year			Average	Conversion factor - weighted [Mg C/m ³]
	2011	2012	2013		
<i>Non-conifer</i>	1,00	1,00	1,00	1,00	0,286
Maple	0,02	0,02	0,02	0,02	
Ash	0,12	0,10	0,10	0,11	
Ash/maple	0,00	0,00	0,00	0,00	
Beech	0,54	0,53	0,54	0,54	
Oak	0,22	0,24	0,24	0,23	
Broadleaves/oth.broad.	0,10	0,10	0,09	0,10	
<i>Conifer</i>	1,00	1,00	1,00	1,00	0,235
Spruce/fir	0,95	0,96	0,94	0,95	
Other conifer	0,05	0,04	0,06	0,05	

⁴ Primarely *Quercus robur* L. and *Quercus petraea* (Mattuschka) Liebl.

⁵ *Acer pseudoplatanus* L.

⁶ *Fraxinus excelsior* L.

⁷ Primarely *Betula pubescens* Ehrh. and *Betula pendula* Roth.

⁸ Primarely *Pinus sylvestris* L., *Pinus contorta* Dougl., *Pinus mugo* Turra and *Pinus nigra* Arnold

⁹ *Abies nordmanniana* (Stev.) Spach.

¹⁰ *Abies procera* Rend.

2.4.1.3 Regional roundwood consumption rates

The growth rate, U , estimated for the region of Europe is applied (IPCC, 2006), i.e. $U = 0.0148$.

2.4.2 Activity data – sources

In Denmark historical data on production, import and export of roundwood and SFWP are available from two sources: FAO-STAT – for the period 1961-2013, and Statistics Denmark – for the period 1988-2013. Statistics Denmark has data going further back than 1988, but these are only available through written publications and thus have not been used in this reporting.

2.4.2.1 Statistics Denmark

Statistics Denmark, the official statistical office in Denmark, produces primary statistics both in monetary value and physical units. Relevant for this project is the statistics on the harvest in the forests, the commodity statistics and the statistics on international trade on roundwood and SFWP. The commodity statistics has a limited use, as many producers of SFWP further refine their products before they are sold and thus the produced SFWP is not registered, resulting in an underestimation of the total production.

2.4.2.1.1 The harvest in the Danish forests – production of roundwood

The statistics on the annual harvest in the forests is based on a questionnaire sent out by Statistics Denmark to all major forest owners and a proportion of the smaller forest owners that are obliged to report back. The data are considered quite reliable, although the collection method is expected to result in a somewhat conservative estimate of the harvest.

An important change in the estimation of the harvest was introduced starting from 2012. This was due to a discrepancy between Statistics Denmark results and the estimation of the harvest in the NFI - the harvest level reported by the latter was considerably higher than the one reported by the former. Consequently the estimation procedure of Statistics Denmark was changed resulting in an increase in the annual harvest of about 20%.

Even though the FMRL calculation is based on harvest levels this change in estimation procedure has no implication on the calculation of the FMRL for the second commitment period, because the harvest data for 2012 has been adjusted to align with the previous harvest estimations according to the above mentioned increase (cf. Johannsen et al., 2011 – page 10-12).

2.4.2.1.1.1 Semi-finished wood products

Statistics Denmark does not register the production of SFWP. The larger sawmills (sawmills with more than ten employees) are required to report their annual sale of commodities, but because some sawmills further refines the sawnwood to other products such as floorings, furniture components etc. the sales statistics does not fully reflect the production of sawnwood. On the other hand Statistics Denmark does register the import and export of sawnwood. These data are based on monetary value and reported in both volume and area units.

2.4.2.2 FAO-STAT

FAO-STAT is the statistical office of the FAO. Their database includes statistical data on production, import and export of roundwood and SFWP, as reported by member states. Therefore using FAO-STAT data in the estimation of inflow to the HWP pool would be an obvious choice - if the data meets the requirements on transparency and validation as outlined by the 2013 KP supplement (IPCC, 2014 – page 2.111).

FAO-STAT data is for the most part based on primary data from Statistics Denmark. As production data on SFWP is not available from Statistics Denmark, FAO-STAT data on this originates from other sources – either expert/subjective assessments or minor surveys of the sawmilling industry. The authors are aware of the existence of some older surveys that undoubtedly has been used in the reporting to FAO-STAT (Trærådet, 1987; Suadicani, 1990; PLS Consult, 1996 and Sørensen, 1998).

2.4.2.3 Questionnaire on the production of the Danish wood industry

In order to improve the data foundation and quality for the reporting a questionnaire was sent out to the Danish wood industry in June 2014. Based on the Danish Central Business Register and taxation information from Statistics Denmark a list of all the relevant companies was generated – i.e. companies with sawmilling equipment or capacity to produce wood-based panels (currently there is only a very limited production of pulpwood in Denmark). Of the latter there was only one company.

The objective was to obtain production figures for the years 2011, 2012 and 2013 for the individual companies in order to estimate the total production of sawnwood and wood-based panels. The questionnaire was then sent out to all of the companies by letter. Following this, visits were made to the larger companies and phone calls made to non-respondents in the following months. Furthermore the relevant branch organization contacted member companies, which constituted the majority of the industry, and encouraged them to participate.

The Questionnaire was deliberately specified so as to give the companies a high degree of latitude when responding - the only demands were that the production was stated in cubic meters solid volume and specified to at least conifer or non-conifer. Furthermore the companies were requested to report the consumption of roundwood and the origin of the wood.

The results from the Questionnaire mean that a more precise estimate of the total production of SFWP can now be made, compared with using the commodity statistics from Statistics Denmark.

The results from the Questionnaire are outlined in Section 3.1.

2.5 Correction of data

2.5.1 General comments on data material

A closer examination of data from FAO-STAT and Statistics Denmark revealed several inconsistencies – especially concerning the production of sawnwood. The development over time, as shown by the data, has in years been quite abrupt – concerning both roundwood consumption and sawnwood production. Sometimes this can be explained by severe windthrow events (e.g. in the years 1967, 1981 and 1999) or sudden shifts in the economic trends (e.g. recessions). But at other occasions no such explanations exist – invariably this questions the validity of data. The reason for this is probably that identical production levels have been reported for adjacent years if no better estimate has been available. When then some single survey has shed light on the sector, this has caused a rapid change in the production level reported in the data. This has given acceptable estimates in periods with only minor changes in the sector and in periods, where surveys have been made regularly. However in the last 17 years no surveys have been made and at the same time the sector has been through a period of very rapid adjustments caused by the globalisation and the financial crisis. Therefore a need was identified for validation of the production data, especially concerning sawnwood.

Comparing the production of sawnwood to the consumption of roundwood reported, often reveal very high utilisation rates, sometimes even over 100%. Thus the data is not internally consistent between categories. It must be noted that when calculating utilisation rates, one is dependent on the correct reporting of volumes to the different categories of roundwood. Furthermore mandatory reporting to Statistics Denmark by the industry often occurs in monetary values. A conversion to volume units (cubic meters) are then carried out. Examination of the unit prices based on the reported revenues and volumes shows that these are sometimes unrealistically high or low - again this questions the validity of data.

For some years reported figures on roundwood flows yields a negative domestic consumption, due to very high amounts of exported wood. In other years exports has exceeded the production, both for roundwood and SFWP, but this may be explained by re-exports, i.e. that imported wood is being exported again. Concerning wood-based panels, this seems probable for some years, as some of the exported volume originates from products, which are not produced domestically. For roundwood and sawnwood this is not as easy to document -the export of products originating from species, from which a limited production is expected (based on silvicultural data and common knowledge) could indicate re-export.

Apart from re-export, there may be several causes for these inconsistencies:

- Reporting of faulty values
- Products may be reported in the wrong categories, i.e. roundwood reported for production of lumber may in fact be wood used for industrial purposes – and vice versa
- Uncertainties when converting value to volume, as calculations are probably based on some guessed average conversion factors

The reporting of the production of sawnwood to FAO-STAT has largely been based on best guesses and expert assessments. Furthermore the reporting has been carried by different institutions over time decreasing continuity over time. As a result of this, much knowledge on the reporting has been lost.

There will probably always be substantial uncertainties related to this type of data, and this limits the demand one may put on the degree of external and internal consistencies, but what is seen regarding the current available data exceeds, what we believe is an acceptable amount of inconsistency. As a result of this a questionnaire was sent out to the industry, where they reported their production of semi-finished wood products (sawnwood and wood-based panels) for the years 2011, 2012 and 2013. These figures also supported the notion that there is a problem with the validity of data. The results from the Questionnaire is directly included in the reporting - see Sections 2.4.2.3 and 3.1 for further details on the Questionnaire.

As a result of the lack of validity of data, the historic data (1961-2010) applied for this reporting is based on extensive corrections on the data from FAO-STAT and Statistics Denmark. This is described in the following section.

2.5.2 Validation and corrections

In this section an overview is provided on activity data as to the sources, the methods of validation and the specific corrections of the data.

Data on inflow to the HWP pool is applied from three sources: FAO-STAT, Statistics Denmark and the Questionnaire on the production of the Danish wood industry:

- From 1961-1989: Data from FAO-STAT – corrected
- From 1990-2010: Data from Statistics Denmark – corrected
- From 2011-2013: Data from Questionnaire – not corrected

It must be noted that the importance of data precision/accuracy increases with proximity to the present - i.e. the older the data the less influence on the present carbon stock and outflow. Thus for an efficient use of resources on validation, these must be prioritised towards the most recent data. In relation to this reporting, the data foundation for the years 2008-2012 is crucial, as it constitutes the input to the calculation of the FMRL.

2.5.2.1 Roundwood and sawnwood

Concerning data from FAO-STAT and Statistics Denmark, it is the general assessment that data on roundwood production is more reliable than the data on sawnwood production. This is based on the fact that roundwood figures originates from direct reporting by forests owners as described earlier, while data for sawnwood production is based on a combination of expert assessments/best guesses and irregular statistical surveys made for other purposes. In FAO-STAT data, it is often observed that figures are often identical over several years, as mentioned earlier.

In principle figures reported to FAO-STAT should be identical to those reported by Statistics Denmark, but this is not the case. This could be due to the fact that figures reported to FAO-STAT are preliminary estimates for the given year, as the reporting occurs earlier in the year than when the final figures are made available by Statistics Denmark. The figures in FAO-STAT have apparently not been updated subsequently. Figure 1 show the production of roundwood in the period 1990-2012 as reported in FAO-STAT and Statistics Denmark. Clearly there is some deviation between the curves, however the magnitudes are similar and they seem to capture the same trends, except in the last five years (2007-2012).

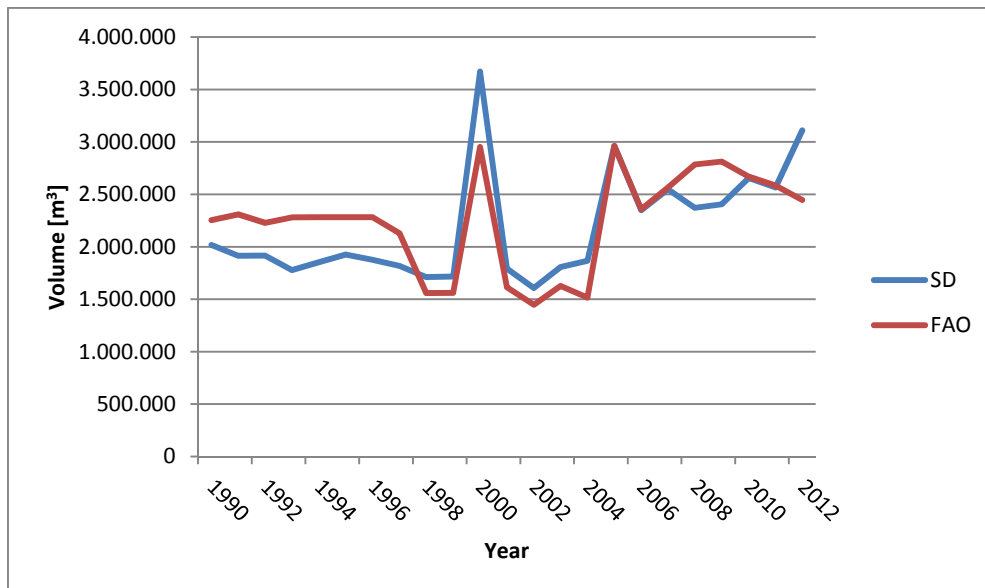


Figure 1. The production of roundwood 1990-2012 - comparison between data from FAO-STAT (FAO) and data from Statistics Denmark (SD).

Figure 2 shows the production, import and export of industrial roundwood reported to FAO-STAT from 1961-2012, along with the domestic consumption calculated as production plus import minus export. Among other things it shows that production and export follow similar trends, which is also to be expected. The major peaks of the production curve coincide with major windthrow events.

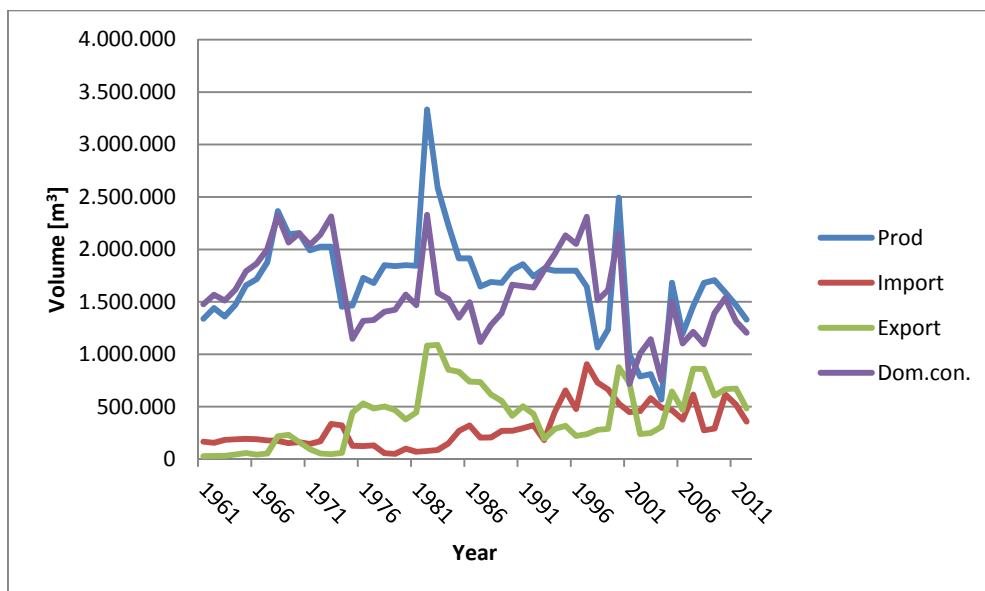


Figure 2. Production (Prod), import, export and domestic consumption (Dom.con.) of industrial roundwood 1961-2012 - based on data from FAO-STAT.

In conclusion it is the assessment that the data on roundwood production is sufficiently reliable to be used in this reporting. As for data on import and export of roundwood this is in general also the case, however sometimes data for certain periods had to be omitted – this will be elaborated on in the following section.

2.5.2.1.1 Market developments

The globalisation and the financial crisis has caused a marked reduction of sawmills in Denmark, which means that the Danish sawmills currently are not able to consume the total harvest of timber from the Danish forests. In addition to this there has been an increased demand for hardwood lumber from countries such as China. Therefore increasing proportions of timber, both conifer and non-conifer, are exported to the neighbouring countries as well as to countries further away.

The globalization has also meant that the import of industrial roundwood has increased. Some qualities are not marketed in Denmark, and others can be bought cheaper elsewhere - partly caused by the increasing market for fuelwood, the quantities of the lower qualities of industrial roundwood have decreased.

Most of the remaining industrial roundwood used for other purposes than sawmilling is exported. There is only one producer of wood-based panels (particleboards) in Denmark, and for this factory roundwood only constitutes about one half of the raw material for the production, the rest coming from wood waste and sawdust. There are no pulp production facilities in Denmark, and therefore all pulpwood is exported.

2.5.2.1.2 Validation

FAO-STAT data on sawnwood production has been validated by comparing with the domestic consumption of roundwood - hereby estimating an utilisation rate for the use of roundwood. It is known by experience that the utilisation rate lies around 50% (Suadicani, 1990) - the results from the Questionnaire are in accordance with this figure; 44% is calculated for conifer and 47% for non-conifer (average for 2011, 2012 and 2013).

Figure 3 and Figure 4 show a comparison between the production of sawnwood and the 50%-share of domestic roundwood consumption for conifer and non-conifer in the period 1961-2012. The two curves should ideally be almost similar. Looking at conifer, evidently, this is not the case for a significant part of the period – most noticeably between 1984-1996, where the production curve lies significantly above the 50%-curve indicating an overestimation of the production. The peaks in the years 1982, 2000 and 2005 for the 50%-curve correspond to major windthrow events. For non-conifer the two curves actually follow quite similar trends, except for the periods 1975-1990 and 2009-2010, where the sawnwood production curve is also located clearly above the 50%-curve. The peak in 1968 corresponds to a major (and unusual) windthrow event in broadleaved species. Thus for both species group a possible overestimation of the sawnwood production has occurred in certain periods.

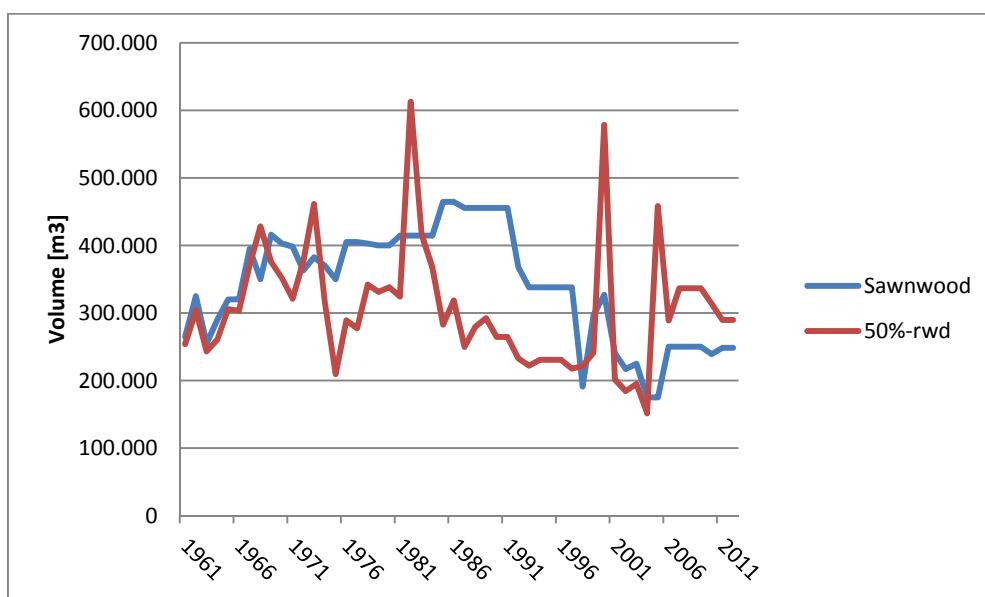


Figure 3. Production of conifer sawnwood compared with the 50%-fraction of the domestic consumption of roundwood (50%-rwd) for 1961-2012 - based on data from FAO-STAT.

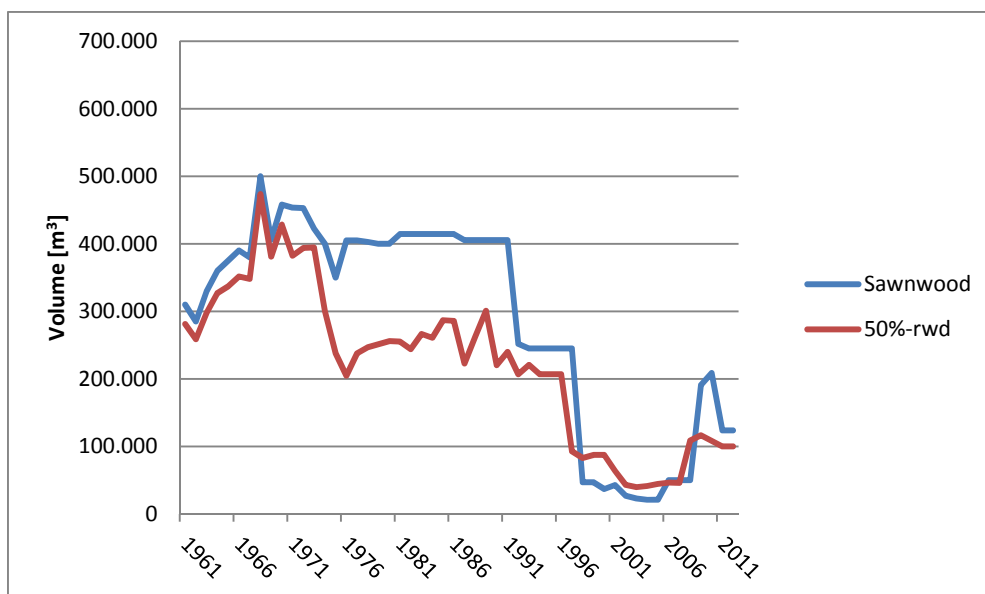


Figure 4. Production of non-conifer sawnwood compared with the 50%-fraction of the domestic consumption of non-conifer roundwood (50%rwd) for 1961-2012 – based on data from FAO-STAT.

For the period 1990-2010 the same validation was made by comparing FAO-STAT data on sawnwood production with Statistics Denmark data on domestic roundwood consumption - see Figure 5 and Figure 6. The curve for conifer sawnwood lies above the 50%-curve for most of the period, while the opposite is true for non-conifer. In conifer the rapid drop in the 50%-curve in 2001 may be explained as a repercussion caused by the major windthrow event in late 1999. The curve for sawnwood shows no such fluctuation. Furthermore is noted that the 50%-curve is negative in some years for both species group – i.e. there is a negative consumption of roundwood.

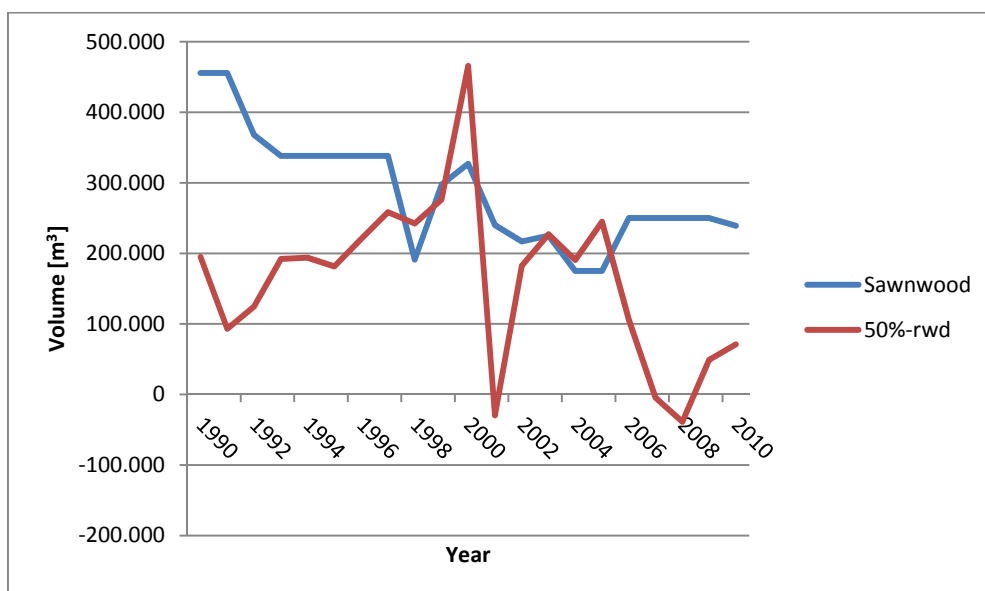


Figure 5. Production of conifer sawnwood compared with the 50%-fraction of the domestic consumption of roundwood (50%-rwd) for 1961-2012 - based on data from Statistics Denmark.

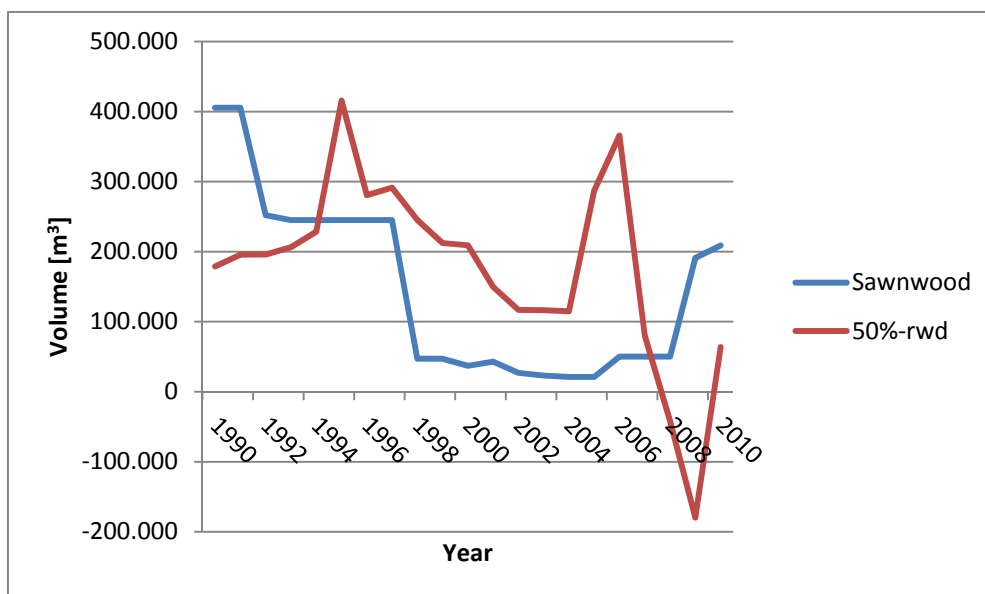


Figure 6. Production of non-conifer sawnwood compared with the 50%-fraction of the domestic consumption of roundwood (50%-rwd) for 1961-2012 - based on data from Statistics Denmark.

The volume of imported and exported roundwood is based on converted monetary value. By comparing volume and revenue, i.e. calculating the mean price for the reported figures, it has been possible to validate the data. Price variation has been quite large, except for exported conifer roundwood. Some very high prices and low volumes have been observed, indicating underreporting of roundwood volumes. The opposite has also been the case. Overall, though, the figures seem to be sufficiently reliable.

2.5.2.1.3 Changes in reporting categories

The estimation of an utilisation rate depends on the ability to estimate the correct amount of roundwood entering the production for the given species group. As for the FAO-STAT data, the reporting categories for roundwood consumption have changed over time. Until 1990 it was possible to separate the roundwood used for sawnwood production ("Sawlogs+veneer logs") from roundwood used for other purposes. After 1990 the data on imported and exported roundwood was pooled in one category ("Industrial roundwood wood in the rough") – see JFSQ for definition of roundwood categories (FAO et al., 2014). Thus it is not possible to estimate utilisation rates after 1990 by just applying the given figures reported in the categories. As FAO-STAT data are applied only from 1961-1989, this change has no influence on estimations. For Statistics Denmark data categories for roundwood consumption have also changed through time depending on the species group. For 1988-1995 only one category was used for conifer. From 1996-2001 this was replaced by three categories making it possible to separate certain species and use of roundwood (to some degree). From 2002 and onwards it has been possible to distinguish between roundwood for production of sawnwood and roundwood for other uses. For non-conifer species the picture has been the same, except in the period 1988-1995, where several categories existed. In general the difficulty, when estimating the amount of roundwood used for sawnwood production for conifer and non-conifer, is that certain categories used in some periods have been so widely defined that they would fit both conifer and non-conifer species or several roundwood uses (including sawnwood production).

2.5.2.1.4 General corrections

Based on the validation it was decided *to estimate the production of sawnwood by the production of roundwood* as reported by FAO-STAT (1961-1989) and Statistics Denmark (1990-2010) *multiplied by an estimated utilisation rate of roundwood* from the Questionnaire (Qs) – Equation 12 and 13:

$$Sawnwood_{Production} = Roundwood_{Consumption} \times Utilisation\ rate_{Qs} \quad (12)$$

Where:

$$Roundwood_{Consumption} = Roundwood_{Production} + Roundwood_{Import} - Roundwood_{Export} \quad (13)$$

As stated, the utilisation rate is the rate calculated from the Questionnaire data for conifer (44 %) and non-conifer (47 %) – see also Section 3.1 on results from the Questionnaire. It is found reasonable to apply these rates to the data of 1961-2010, as they represent the best estimates available and production of sawnwood has largely not changed in this respect – i.e. a round commodity still has to be converted into a square one.

Thus the FAO-STAT figures on production and export of sawnwood for 1961-2012 is not applied in this reporting. From 2011-2013 figures from the Questionnaire is applied. In the following the details of the specific corrections are described.

In the years of major wind throw events the production of roundwood increases quite dramatically due to salvage harvest operations. However assuming that the capacity of sawmills is fixed, the production of sawnwood will not increase accordingly leading to an oversupply of roundwood. This is partly handled by an increasing export (as can be seen in Figure 2) as well as by water storing the harvested wood. Furthermore the proportion of other assortments in the harvest, e.g. fuelwood, may increase. When looking at Figure 2 this is reflected in the data, as the curve on roundwood production is affected to higher degree than would be the sawnwood production (curve not shown). *Thus the sawnwood production in a year following a major windthrow event is estimated by interpolation between the two adjacent years.* The same method is used to even out fluctuations, which either cannot be explained or leads to infeasible results.

2.5.2.1.5 Corrections – FAO-STAT data 1961-1989

Data on roundwood used for sawnwood production are based on the JFSQ categories “Sawlogs+Veneer Logs” (FAO-STAT codes 1601 for conifer and 1604 for non-conifer). The following year-specific corrections have been made:

- **1968** - Sawnwood production for non-conifer estimated by linear interpolation between 1967 and 1969, due to the windthrow event of 1967.
- **1982** - Sawnwood production for conifer estimated by linear interpolation between 1981 and 1983, due to the windthrow event of 1981.
- **1988 and 1989** - Roundwood export for conifer corrected due to a probable switch-around with pulpwood figures in reporting to FAO-STAT. Roundwood import for non-conifer corrected due to a probable switch-around with pulpwood figures in reporting to FAO-STAT.

2.5.2.1.6 Corrections – Statistics Denmark data 1990-2010

Data on the production of conifer roundwood for sawnwood production are based on Statistics Denmark (SD) categories “Timber”, “Rafters” and “Short timber”. Data on the production of non-conifer roundwood are based on the category “Veneer and sawnwood logs”.

Data on conifer roundwood import and export for sawnwood production is based on:

- **1990-1995** - SD category “Coniferous wood” (code 44032000). The share of roundwood used for sawnwood production is estimated based on the average share from 1996-2001, as 44032000 does not distinguish between different roundwood assortments.
- **1996-2001** - SD categories “Timber of norway spruce or silver fir” and “Timber of scots pine” (codes 44032010 and 44032030). Furthermore the category “Coniferous wood” (code 44032090) was also used for exports but not for imports¹¹.
- **2002-2010** – SD categories “Roundwood for sawmilling, of norway spruce and silver fir”, “Roundwood for sawmilling, of scots pine” and “Roundwood for sawmilling, of coniferous wood” (codes 44032011, 44032031 and 44032091).

Data on non-conifer roundwood import and export for sawnwood production is based on:

- **1990-2001** - SD categories “Timber of oak”, “Timber of beech”, “Timber of birch”, “Timber”, “Timber, except tropical wood, coniferous wood, oak, beech and poplar” (codes 44039100, 44039200, 44039950, 44039980/44039998/44039999 and 44039990).
- **2002-2010** - SD categories “Roundwood for sawmilling, of oak” and “Roundwood for sawmilling, of beech” (codes 44039110 and 44039210).

Empty categories or categories with only very small amounts of registered wood have been omitted from calculations and are thus not mentioned in the overview to limit complexity.

The following year-specific corrections have been made:

- **1995** - Sawnwood production for non-conifer estimated by linear interpolation between 1994 and 1996, due to an untrustworthy increase in roundwood consumption in 1995.
- **2000 and 2001** - Sawnwood production for conifer estimated by linear interpolation between 1999 and 2002, due to the windthrow event of 1999 in the following repercussions.
- **2005 and 2006** - Sawnwood production for non-conifer estimated by linear interpolation between 2004 and 2007, due to an untrustworthy increase in roundwood consumption in 2005 and 2006.

¹¹ When estimating imported and exported conifer roundwood for the period 1996-2001, the use of the category “Coniferous wood” (code 44032090) differed. Based on sector knowledge there is strong reason to believe that for exports the category also include roundwood for sawnwood production. This is due to the fact that exported roundwood from Denmark is primarily for sawnwood production. For imports it is assumed that the category consists of roundwood for other uses. The differentiated use of the category, tallies with figures from the adjacent periods for both import and export.

- **2008 and 2009** - Sawnwood production for non-conifer estimated by linear interpolation between 2007 and 2010, due to an infeasible decrease in roundwood consumption in 2008 and 2009, leading to negative consumption.
- **2006-2010** - Sawnwood production for conifer estimated by linear interpolation between 2005 and 2011, due to an infeasible decrease in roundwood consumption in the period, leading to a negative consumption.

Figure 7 and Figure 8 show the corrected and non-corrected (FAO-STAT) data for sawnwood production for conifer and non-conifer for 1961-2010 – for 2011-2013 Questionnaire figures are shown as part of the curves.

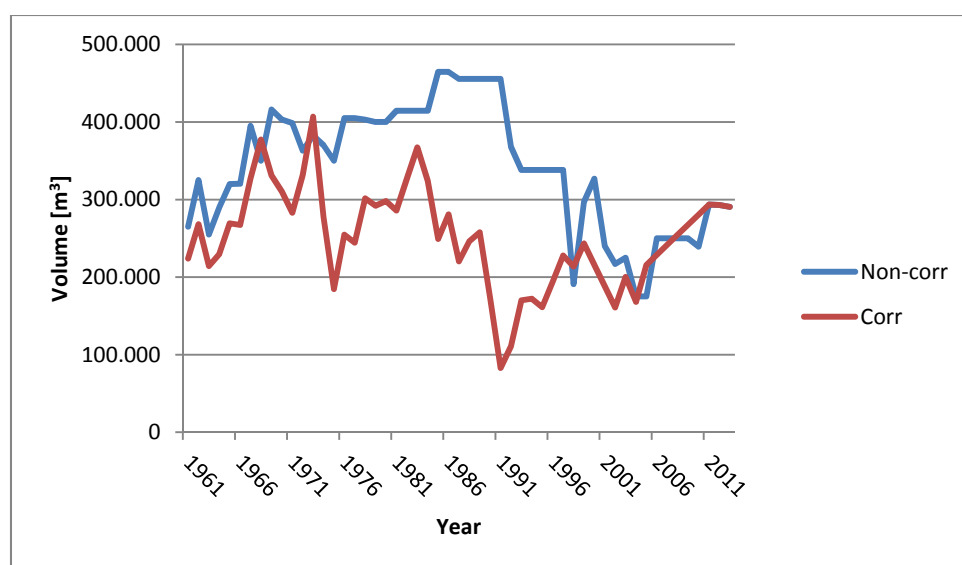


Figure 7. Production of conifer sawnwood 1961-2012: Non-corrected data (FAO-STAT) vs. the corrected data used in the reporting.

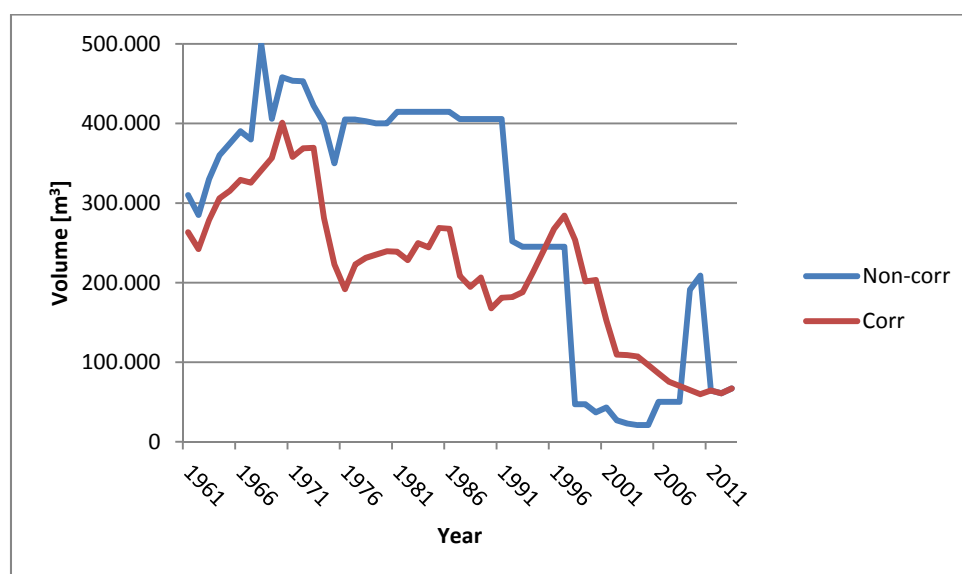


Figure 8. Production of non-conifer sawnwood 1961-2012: Non-corrected data (FAO-STAT) vs. the corrected data used in the reporting.

2.5.2.2 Export ratio – estimating the export of sawnwood

In order to calculate HWP domestically consumed, the export of sawnwood also has to be estimated, as it would be inconsistent to use the data directly from FAO-STAT, when the figures on production have been rejected. Contrary to the production of sawnwood, figures for export of sawnwood can be obtained from Statistics Denmark, but as these are based on monetary value and reported in both volume and area units, they are also considered to be highly uncertainty. Thus, due to a lack of alternative data sources, the data from FAO-STAT have been used to calculate an export ratio to estimate the amount of exported sawnwood – noting the obvious drawbacks of this.

The development of the ratio for conifer and non-conifer from 1961-2012 is shown in Figure 9. Until 1998 the ratio has been consistently under 0,5, with some variation between years. However from 1998 the ratio increases rapidly and stays almost consistently above 1,0, reaching as high 4,5 as for non-conifer. For comparison the export ratio calculated by Questionnaire data for 2011-2013 is also shown in Figure 9. It clearly deviates from estimates based on FAO-STAT from the same years, but it corresponds well to the pre-1998 level. The only explanation for a ratio > 1 is re-export – if data is reliable. Either pre-1998 reporting has excluded this or there has been a rapid market development in this respect. It is also possible that it is due to a change in reporting to FAO-STAT. In fact the figures on import of sawnwood reported to FAO-STAT do allow for a high amount of re-export in the period 1998-2012. Thus for the estimation of exported sawnwood the figures from 1998-2010 are excluded. This is consistent with Decision 2/CMP.7, as imported wood must be excluded from the reporting of HWP.

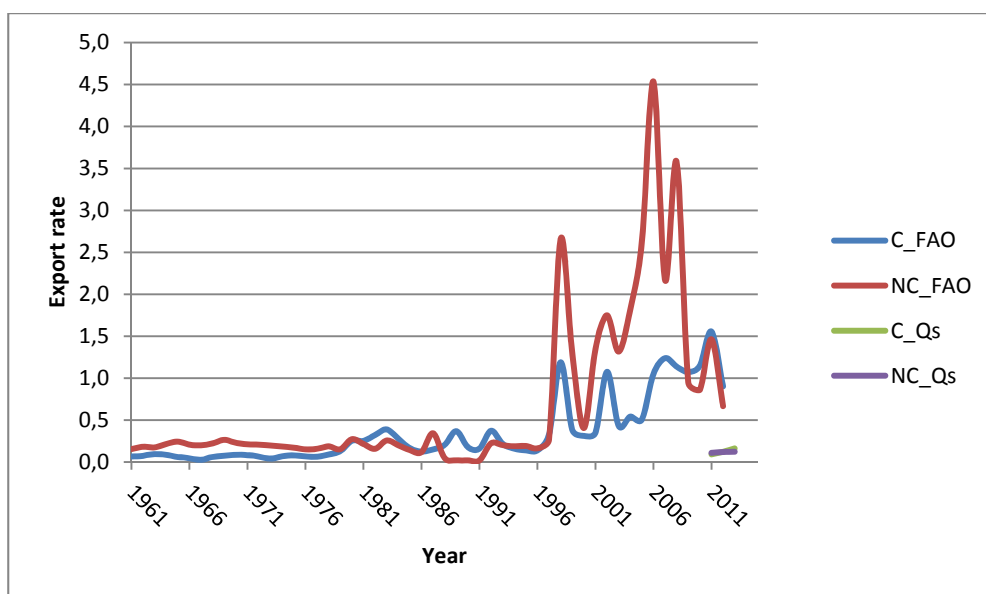


Figure 9. The export rate of sawnwood 1960-2013 calculated as the ratio of export to domestic production for conifer (C) and non-conifer based on data from FAO-STAT (FAO) and the Questionnaire (Qs).

Thus to estimate the export of sawnwood from 1961-2010, the estimated sawnwood production is multiplied with a corrected export ratio (Equation 14):

$$Sawnwood_{Export} = Sawnwood_{Production} \times Export\ ratio_{FAO,corr} \quad (14)$$

The export ratio for the years 1998-2010 was estimated by linear interpolation between 1997 and 2011. The estimated export of sawnwood for conifer and non-conifer sawnwood is shown in Figure 10 and Figure 11 in comparison with the non-corrected data from FAO-STAT.

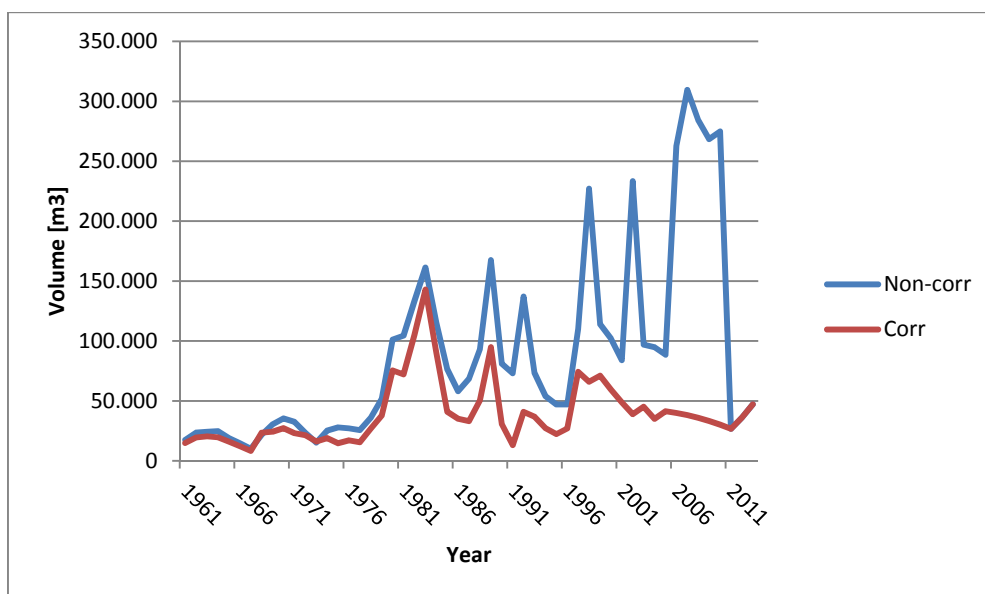


Figure 10. Export of conifer sawnwood 1961-2013: Non-corrected data (FAO-STAT 1961-2010 and Questionnaire 2011-2013) vs. the corrected data used in the reporting.

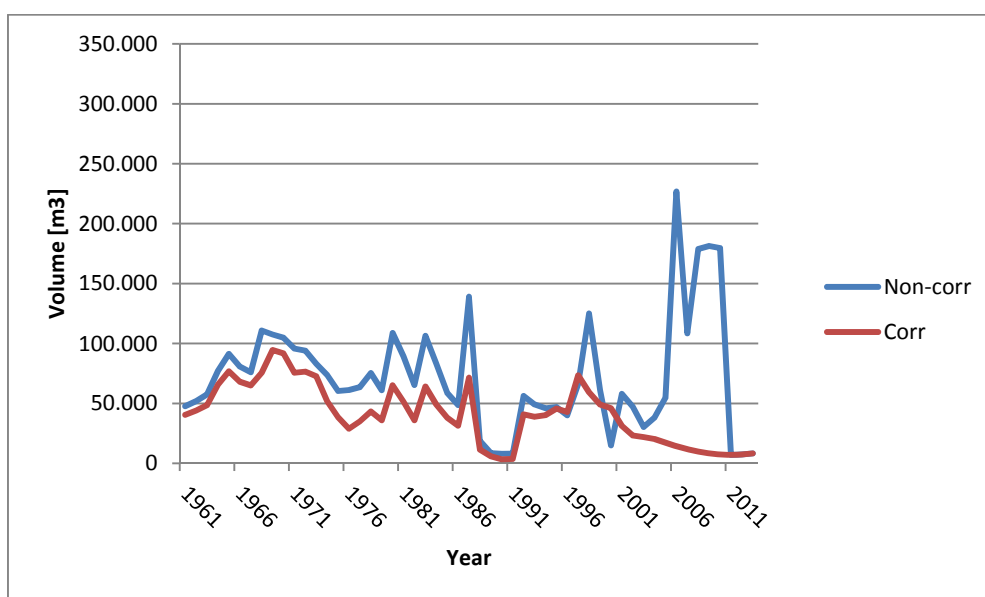


Figure 11. Export of non-conifer sawnwood 1961-2013: Non-corrected data (FAO-STAT 1961-2010 and Questionnaire 2011-2013) vs. the corrected data used in the reporting.

2.5.2.3 Wood-based panels

It has not been possible to validate the production of wood-based panels with the method used for validation of sawnwood production, as the feedstock of roundwood going into the production is difficult to estimate based on the categories used by FAO-STAT, e.g. roundwood for pulp production is mixed with that

for wood-based panels. The production of wood-based panels is also based on scrap wood, which is not specified in the statistics. Furthermore the production capacity in Denmark has been made up of few companies - currently there is only one – and thus one should have been able to obtain accurate data more easily compared to the sawnwood sector. In addition the contribution of wood-based panels to the carbon stock in the pool HWP historically has been secondary to that of sawnwood - although the share has been steadily increasing. As of 2013 the share of carbon in the HWP pool originating from wood-based panels was 34%. Thus uncorrected data from FAO-STAT have been used to estimate the HWP pool from wood-based panels. Only for 2006 a correction has been made, due to an unrealistically high production level.

2.5.2.4 Paper

Little effort has been put into validating FAO-STAT data on paper production, import and export. Since 1999 there has only been a very limited production of pulpwood in Denmark, meaning that the paper production originating from domestically harvested wood has been equally limited. With the relatively short half-life (2 years), the contribution of paper to the HWP pool, and thus current emissions, must be expected to be minimal. This is in accordance with FAO-STAT data, as the contribution from paper to the HWP pool constituted 0,006% in 2013. A correction has been made to the pulpwood ratio calculated by the 2013 KP Supplement Equation 2.8.2 (see Section 2.3.2.4) for the years 1991 and 1999-2013 due to negative consumption figures, i.e. the ratio was assumed to be zero for these years.

3 Results

3.1 Results from the Questionnaire

Table 3 shows the production of sawnwood from Danish sawmills for the years 2011, 2012 and 2013 as it was reported by the industry in the Questionnaire. The number of sawmills participating was 13. The average total production reported is about 356.000 m³/year, with low variation between the years (coefficient of variation = 0,6%). In addition is an estimated production of some 5.000 m³/year from one man sawmills.

It was up to the individual mills how they reported their production in relation to tree species, thus the species groups shown in the table are overlapping – e.g. sawnwood of Norway spruce may have been reported as both “Conifer”, “Mixed conifer” and “Norway spruce”. As Norway spruce constitutes the majority of the Danish harvest of conifer timber, this species must also dominate the production of sawnwood accordingly. Otherwise the conifer/mixed conifer groups are expected to primarily be made up of sitka spruce and silver fir. The groups constitute about 95% of the conifer production. Larch makes up about 4%. Beech (≈55%), oak (*Quercus robur* L.) (≈25%) and ash (*Fraxinus excelsior* L.) (≈10%) dominate the non-conifer group. Conifers constitute the majority (≈80%) of the total production. In general the species distribution of the production is as expected. Furthermore the variation over the period is quite low, except for groups with low reported volume.

Table 3. Production of sawnwood distributed to species/species groups as reported by the Danish sawmill industry for the years 2011, 2012 and 2013. Total number of companies: 13. Volume in m³.

Tree species/ species group	Year			
	2011	2012	2013	Average
Maple	1.538	1.479	1.571	1.529
Ash	7.835	6.112	6.966	6.971
Ash/maple	100	90	0	63
Beech	34.673	32.282	35.835	34.263
Oak	13.918	14.632	16.263	14.938
Cherry	38	43	3	28
Broadleaves	6.000	6.000	6.000	6.000
Walnut	221	246	249	239
Conifer	168.721	161.505	154.286	161.504
Mixed conifer	110.712	118.417	119.081	116.070
Norway spruce	45	45	54	48
Douglas fir	1.100	1.341	2.092	1.511
Larch	12.848	11.570	15.202	13.207
Total - Non-conifer	64.323	60.884	66.887	64.031
Total - Conifer	293.426	292.878	290.715	292.340
Total*	357.749	353.762	357.602	356.371

*In addition is an estimated 5.000 m³/year from one man sawmills.

The production of wood-based panels for the years 2011, 2012 and 2013 as reported by the wood panel industry in the Questionnaire is shown in Table 4. The production primarily consists of particleboards and only involves 1 company. The average total production reported is about 350.000 m³/year, with some variation in the period (coefficient of variation = 4%).

Table 4. Total production of wood-based panels as reported by the Danish wood panel industry for the years 2011, 2012 and 2013. Total number of companies: 1.

Wood-based panels	Year			
	2011	2012	2013	Average
Total [m³]	367.000	340.000	346.000	351.000

The reported production is validated in Table 5, by a comparison of the domestic consumption of roundwood for sawnwood production originating from domestic harvest as reported by Statistics Denmark (timber harvest ÷ export) and the reported roundwood consumption from domestic harvests in the Questionnaire. Furthermore the utilisation rate of the roundwood (the ratio of produced sawnwood to consumed roundwood) is also shown. As to the former, the consumption reported by the industry deviates between 4 and 11% from the amount reported by Statistics Denmark – i.e. an average of 8%. Regarding the export the figure covers the total amount of exported roundwood, i.e. the amount of exported timber is probably lower. This may, to some extent, explain why the roundwood consumption, reported by the sawmills, is higher during all three years compared with Statistics Denmark figures. As to the calculated utilisation rate for the total sawnwood production, it varies from 43 to 47%, with slightly higher rates for

non-conifer compared to conifer. For the production of wood-based panels the utilisation rates varies from 72 to 76% (also taking into account wood waste and recycled wood).

Table 5. Validation of production of sawnwood and wood-based panels – Questionnaire vs. Statistics Denmark. Volume in 1.000 m³.

Production and source		Year		
		2011	2012	2013
Production of roundwood, Statistics Denmark				
	Felling, total*	3.465	3.111	3.590
	Timber*	1.429	1.283	1.372
	Export, total**	577	444	519
Production of sawnwood, Questionnaire				
Roundwood	Feedstock-domestic, total	704	648	741
Sawnwood	Production, total	363	359	363
	Utilisation rate	44%	47%	43%
Production of wood panels, Questionnaire				
Roundwood	Feedstock-domestic, total	233	225	215
Wood panels	Production, total	367	340	346
	Utilisation rate***	76%	72%	74%
Roundwood (DH DC) – total				
Questionnaire		937	873	956
Statistics Denmark		852	840	864
Deviation		10%	4%	11%

*Figures corrected for 2011 based on harvest estimates from the Danish National Forest Inventory and 2012 assortment distribution from Statistics Denmark. ** Figures corrected for 2011, 2012 and 2013 based on price/volume relations. *** This also takes into account wood residues and recycled wood $\approx 250.000 \text{ m}^3/\text{year}$.

Table 6 gives an overview of the size distribution of the total number of companies producing SFWP in Denmark based on the annual employment. The sector is comprised of 69 companies, where 14 has registered a production in the Questionnaire, while 55 is missing. However the major companies (employment > 20) are all included.

Table 6. Overview of the companies in the Danish wood industry for production of sawnwood and wood-based panels. Companies divided to size classes based on the annual employment: "Included" = companies with registered production in Questionnaire, "Not included" = companies with no registered production in Questionnaire. Source: Statistics Denmark.

Annual employment	Included	Not included	Total
1	2	42	44
2 - 4	2	7	9
5 - 9	0	4	4
10 - 19	0	2	2
20 - 49	5	0	5
50 - 99	2	0	2
100 - 199	0	0	0
200 - 499	3	0	3
Total	14	55	69

Table 7 shows an estimation of the coverage of the Questionnaire based on the revenue share of the total sector revenue of the reporting companies. The revenue data is derived from Statistics Denmark and the Value added tax register. The Questionnaire covers 95% of the total revenue generated by sawnwood producing companies, and 100% of the revenue in the sector of wood-based panels (as there are only one relevant company).

Table 7. Coverage of the Questionnaire based on the reporting companies' revenue share of the total sector revenue. Based on data from Statistics Denmark.

Sector	Revenue share
Sawnwood production	95%
Wood-based panel production	100%

Aside from the smaller sawmills it is reckoned based on the mapping of the relevant companies that six sawmills with a significant production is missing from the survey. Based on the size (number of employees) of the missing companies, and size/production figures of the participating companies, the amount of produced sawnwood missing from the survey may be - roughly - estimated. This estimate suggests a coverage of around 96% - i.e. in line with the estimation based on the revenue information.

Comparing with the figures reported to FAO-STAT the sawnwood production deviates about 18 % for conifer and 50% for non-conifer. For wood-based panels the deviation is about 25%. Thus especially for non-conifer, there is a very high deviation between the figures. The figures in FAO-STAT are almost identical between the three years and represent only best guesses as described in Section 2.5.

In conclusion the results from the Questionnaire for the years 2011, 2012 and 2013 seem to be quite valid. First, the production level and species composition are in accordance with expectations, perhaps except for the size of the non-conifer production. Second, the result of the cross validation of the roundwood consumption is convincing and utilisation rates lie within realistic boundaries (considering the different production processes). Finally, the Questionnaire covers the clear majority of the companies within the production of sawnwood and wood-based panels in Denmark based on the number employees and the revenue share.

3.2 Carbon stock, inflow and outflow

In this section the development of the carbon stock in HWP originating from FM is accounted for. In Section 2.3.2.3 it was explained how HWP originating from deforestation is estimated and thus accounted for on the basis of instantaneous oxidation, and that the amount of HWP carbon from AR activities is assumed to be zero.

3.2.1 Share of HWP from domestic harvest

Figure 12 show the development of the share of the roundwood feedstock originating from domestic harvest for producing HWP from 1900-2013 (2013 KP Supplement Equation 2.8.1.). From 1900-1960 the curves are straight lines, as the shares are assumed constant, see Sections 2.3.2.2 and 2.3.2.4. For coniferous sawnwood the share (f_{Sawnwood_C}) was very close to 1 until the late 1960's, after which it became more volatile and fluctuated around 0,8 occasionally falling below 0,6. At the end of the period, i.e. where data is available from the Questionnaire, the share increased above 0,9. For non-conifer the share ($f_{\text{sawnwood}_{NC}}$) was considerably lower and dropped dramatically during the 1990's, until it steadily

increased towards 0,5 at the end of the period. That the share in general is lower for non-conifer is in line with known practices for sawmills. The share for wood-based panels ($f_{\text{other ind+pulp}}$) has been somewhat more stable and remained above 0,9 for the much of the period. The Questionnaire determines a share of 1 for 2011, 2012 and 2013. The share for pulp was below 0,5 except for a brief period in the 1990's, where it reached around 0,6. In the last part of the period the share dropped to zero, as the production of pulp was discontinued.

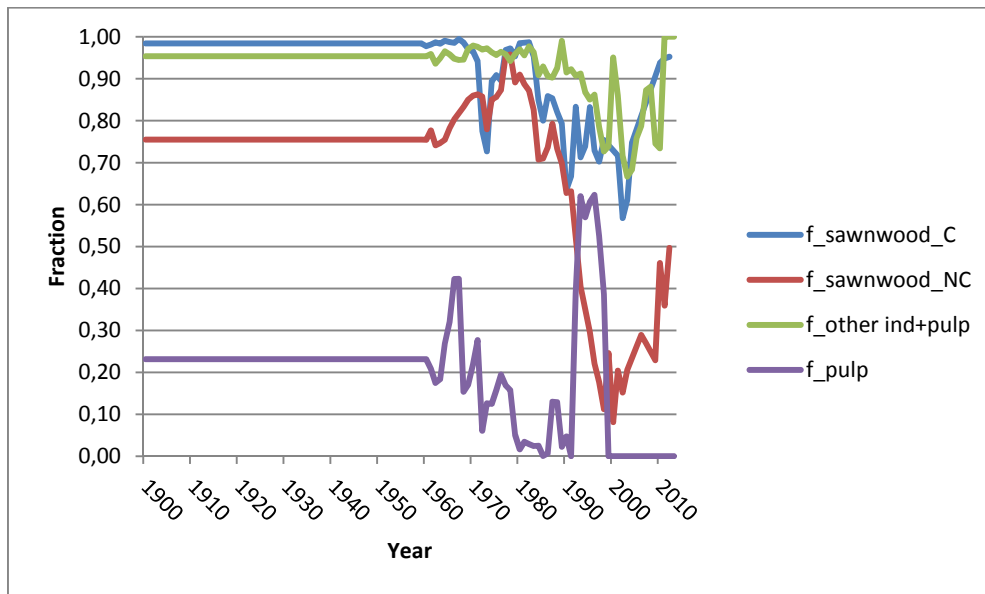


Figure 12. Fraction of the feedstock for production of HWP coming from domestic harvest from 1900-2013. f_{IRW} = fraction of total industrial roundwood, $f_{\text{sawnwood_C}}$ = fraction of conifer roundwood for sawnwood production, $f_{\text{sawnwood_NC}}$ = fraction of non-conifer roundwood for sawnwood production, $f_{\text{other ind+pulp}}$ = fraction of roundwood for wood-based panel and pulp production.

3.2.2 Deforestation

Figure 13 shows the share of the total harvest originating from deforestation from 1990-2013. From 1900-1960 the deforestation area is assumed to be constant, thus the deforestation share is continuously decreasing through the period, as the harvest is assumed to have been constantly increasing (see Section 2.3.2.2). From 1961 onward the share fluctuated between 0,3% and 2,1% averaging 1,2%. The volatility was significantly higher in the 2000's compared to the rest of the period.

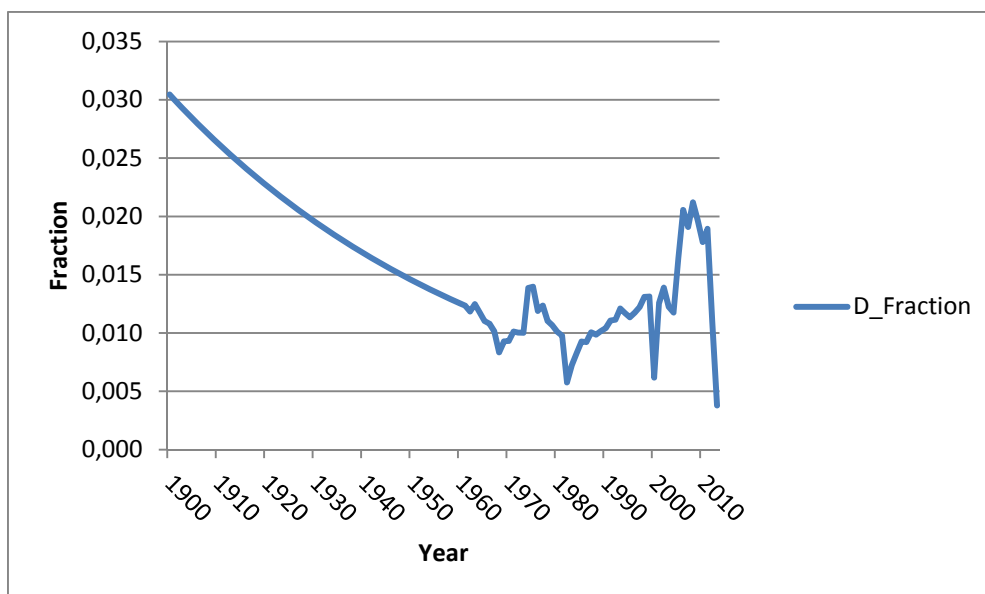


Figure 13. The share of the total harvest originating from deforestation from 1900-2013.

3.2.3 Inflow and outflow

Figure 14 shows the inflow (in Mg, or metric tons¹², carbon) to the HWP pool for the different categories. Until the late 1980's sawnwood was the largest contributor to the pool with an inflow averaging about 80.000 Mg C from 1960-1990. Afterwards wood-based panels have dominated with an inflow fluctuating around 60.000 Mg C increasing to above 80.000 at the end of the period. From the mid 2000's the inflow from sawnwood has also been steadily increasing. The contribution of paper has been of minor importance, except from a brief period in the 1990's.

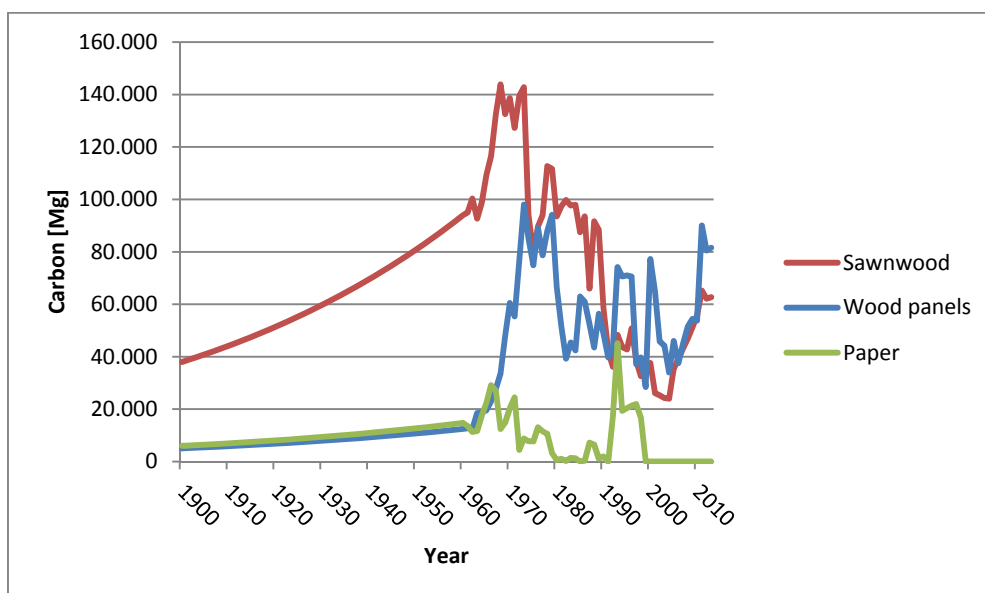


Figure 14. Inflow to the HWP pool for the different categories from 1900-2013.

¹² In general Mg is used, as grams is a SI unit as opposed to tons. In this report "tons" exclusively refer to "metric tons".

Figure 15 summarises Figure 14 showing the total inflow to the HWP pool. Furthermore the total outflow from the pool is also shown, with a comparison of the methods of the 2006 IPCC Guidelines and 2013 KP Supplement (differences in starting conditions, see Section 2.3.2.1). The inflow increased from 1900 until 1973 (partly due to the assumption of steady growth from 1900-1960), where it peaked at about 250.000 Mg C. Afterwards a period with a general decrease (with large fluctuations) followed until the early 2000's, where the inflow started to increase again reaching about 140.000 Mg C in 2013. The outflow-curves are smoother due to the application of the FOD-model. Both curves increase along with the inflow (there is a lag, as the stock is build up) peaking in 1997 with about 130.000 Mg C (KP method). The difference in starting conditions between the two methods is clearly visibly, but as expected it decreases over time as the initial stocks decayed. The KP outflow is larger, due to the larger initial stock. In respect to the accounting, this has no influence, as differences will cancel out each other (the same method must be used to calculate the FMRL and the reported net-emissions to ensure consistency).

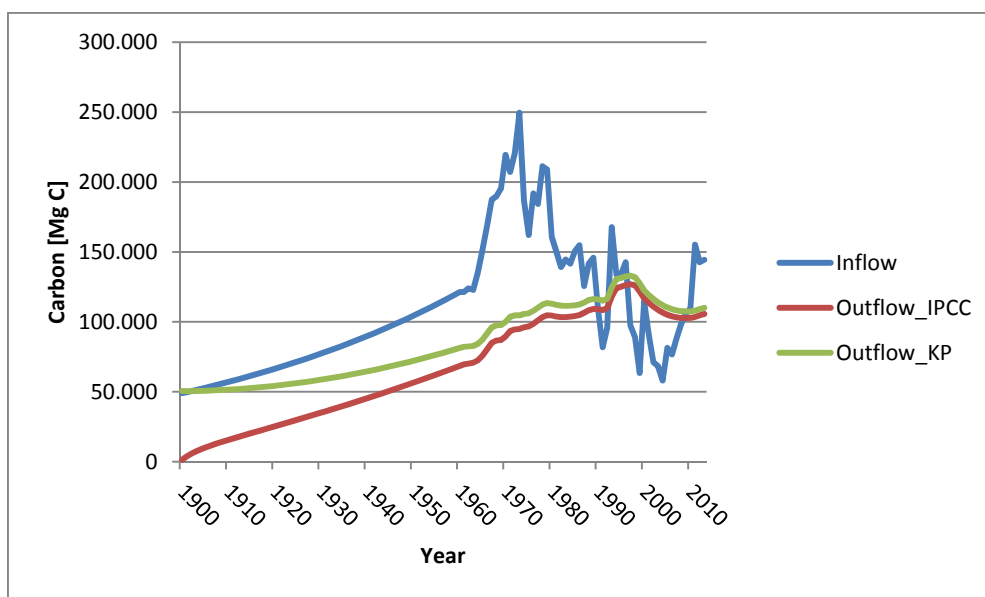


Figure 15. Total inflow to HWP pool compared with total outflow from pool based on the methods of the 2006 IPCC Guideline (Outflow_IPCC) and 2013 KP Supplement (Outflow_KP) from 1900-2013.

The total changes in the HWP pool from 1900-2013 is shown in Figure 16. Once again the differences between the 2006 IPCC Guidelines and the KP 2013 Supplement is apparent, as the former had a noticeably higher increase in the pool early in the period due to the initial stock of zero. In 1960 the change of the IPCC model constituted 133% of the KP model corresponding to a difference of about 15.000 Mg C. In 2013 the difference was reduced to 113% or 5.500 Mg C. The difference between using corrected or non-corrected data is largest in the period 1995-2010, where the decrease in the stock is markedly higher for the non-correction. It fluctuated around -100.000 Mg C, compared to a level of -25.000 Mg C for the correction. In 2013 the correction shows an increase of about 34.000 Mg C, or 12.000 Mg C more than the non-corrected.

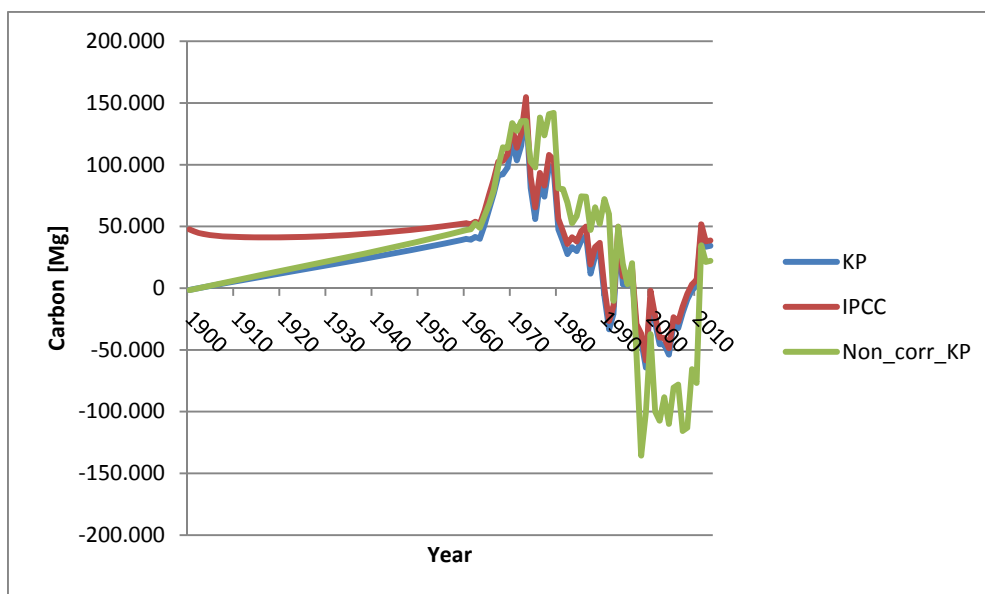


Figure 16. Total change in the HWP pool from 1900-2013 for the 2006 IPCC Guidelines (IPCC) and 2013 KP Supplement (KP) - for the latter the change is also shown with non-corrected data (Non_corr_KP).

Corresponding to Figure 15 and Figure 16, Figure 17 shows the development of the total stock. For the KP method the stock peaked in 1990 at about 5,2 Mio. Mg C, 350.000 Mg C more than for the IPCC method. In 2013 the stock had decreased to 4,9 Mio. Mg C for the KP method, though showing an increasing tendency. Comparing with the non-correction, the stock is decreased noticeably by the correction – consistent with the pattern seen for the outflow. The stock peaked at 6,8 Mio. Mg C in 1997 followed by a significant decrease resulting in a stock in 2013 of about 5,6 Mio. Mg C.

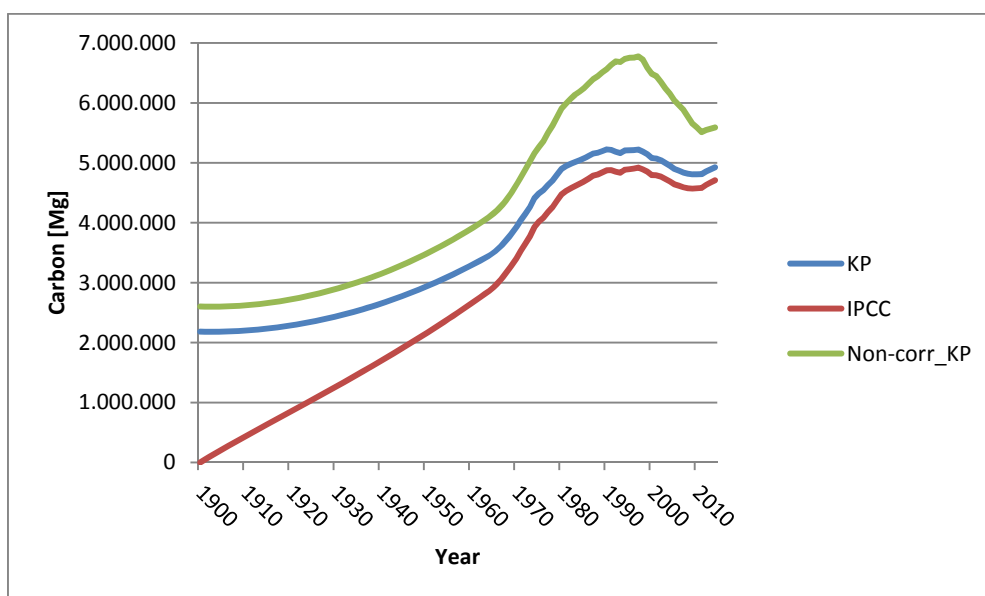


Figure 17. Development of the total carbon stock in the HWP pool from 1900-2013 – comparison of corrected and non-corrected data.

Figure 18 show the development of the carbon stock for the different HWP categories. Clearly sawnwood has been the dominant category for the HWP pool, but wood-based panels have gained increasing

importance, whereas paper shows a very limited storage. In 2013 the sawnwood pool consisted of about $3,3 \cdot 10^6$ Mg C corresponding to 67% of the total pool, while wood-based panels consisted of about $1,6 \cdot 10^6$ Mg C corresponding to 33% of the total pool.

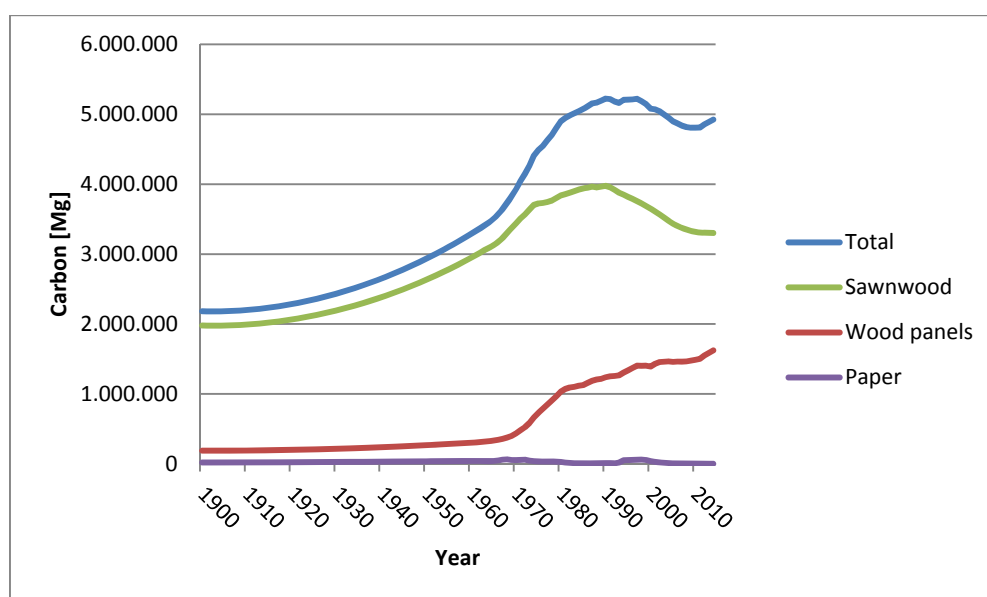


Figure 18. Development of the carbon stock in the HWP pool for the different categories from 1900-2013.

If the carbon stock in the HWP pool were to be maintained at the 2013 level with the same composition it would require an annual inflow of about 65.000 Mg C (251.000 m^3) from sawnwood and 45.000 Mg C (167.000 m^3) from wood-based panels (using 2013 KP Supplement Equation 2.8.5), in total 110.000 Mg C – i.e. considerably less than the inflow in 2013 (144.000 Mg C).

Table 8 provides an overview of the figures for the HWP pool in 2013, as they will be reported to the UNFCCC. The total net emissions from the pool were $\div 125.692$ Mg CO₂ equivalents (eq.), i.e. there was a net sequestration of carbon in HWP in 2013 corresponding to this amount of CO₂.

Table 8. Figures for 2013 reporting to UNFCCC on HWP - domestically harvested (DH) and domestically consumed (DC).

HWP _{DH DC} 2013	Stock	Inflow	Outflow	Half-life	Annual change in stock	Net emissions
	[Mg C]	[Mg C]	[Mg C]	[years]	[Mg C]	[Mg CO ₂ eq.]
Sawnwood	3.300.880	62.722	65.398	35	-2.675	9.803
Wood-based panels	1.623.118	81.595	44.490	25	37.104	-135.961
Paper	307	0	127	2	-127	466
Total	4.924.305	144.317	110.015		34.302	-125.692

The total carbon stock in the HWP pool corresponds to approximately 0,9 Mg C/capita or 13% of the carbon stock in the live biomass in the Danish forests. The sequestration of carbon corresponds to 0,13% of Denmark's total CO₂-emissions for 2012 (93,3 Mio. tons CO₂).

If HWP carbon from imported wood and deforestation areas is also included (i.e. ignoring the restrictions imposed by 2013 KP Supplement Equation 2.8.1 and 2.8.3) the total stock increases to 28,8 Mio. Mg C (using non-corrected import figures) corresponding to approximately 5,1 Mg C/capita or 75% of the of the carbon stock in live biomass in the Danish forest. The carbon sequestration would amount to 632.000 Mg CO₂ eq. corresponding to 0,68% of Denmark's total CO₂-emissions for 2012.

Figure 19 shows the development of the total stock including imported wood in comparison to the reported HWP stock. The effect of including imports is apparent. The increasing imports since the 1960s is clearly visible from the rapid expansion of the HWP pool including imported wood compared to reported HWP pool.

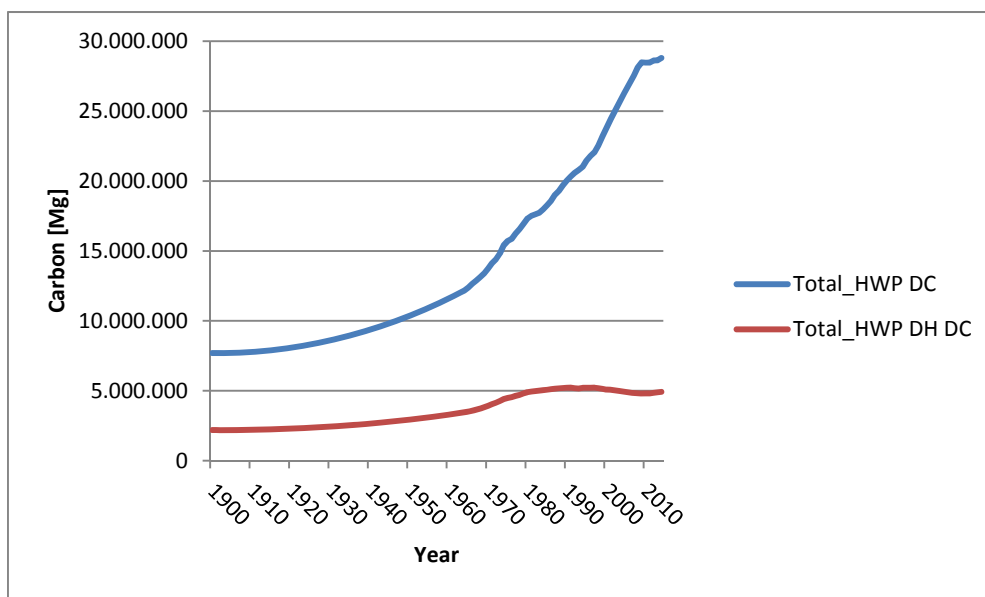


Figure 19. Comparison of total stock estimations of carbon in HWP. Total_HWP DC = total carbon stock, domestically consumed incl. imported wood, HWP DC DH = total carbon stock, domestically harvested and consumed, Total_HWP DC FWP = total carbon stock, domestically consumed incl. imported wood for finished wood products.

Assuming an average loss of 25 %¹³ when processing SFWP and excluding paper this would correspond to about 21 Mio. Mg C in finished wood products (FWP) or 3,7 Mg C per capita. In comparison Pingoud et al. (2001) estimated the total HWP pool in Finland in 1995 (for FWP excluding paper) to constitute some 16,5 Mio. Mg C corresponding to 3,3 Mg C per capita or 2,4% of the carbon stock in Finnish forest biomass – using a direct inventory method¹⁴. The Danish figures corresponds quite well to the Finnish in that the amount of stored carbon per capita is quite similar and that the total stock constitute a much larger share of the forest biomass, as the Finnish growing stock is considerably larger than the Danish growing stock (about 20 times according to FAO (2010)) - noting the difference in years between the stock estimations of the two countries and the related uncertainties.

What makes the Finnish estimate interesting is that it is based on a direct inventory of the carbon stock in the HWP pool and thus is derived using a different method than the IPCC default approach employed in the

¹³ Best guess.

¹⁴ The inventory employed data mainly from statistics on the Finnish building stock

Danish estimation. As such the comparison provides an indication that the HWP stock estimate for Denmark seems reasonable, though the uncertainty surrounding these estimates must be emphasised.

3.2.4 Forest Management Reference Level - correction

As described in Section 2.3.3 the FMRL has been corrected using new and corrected data and a reference period from 2008-2012 instead of 2005-2009. Figure 20 shows the projected harvest for the second commitment period (2013-2020) relative to the average harvest 2008-2012, which was about 2,46 Mio. m³. The reported harvest for 2012 was multiplied by a factor of 0,74 to account for a change in methodology by Statistics Denmark (cf. Section 2.4.2.1.1 and Johannsen et al., 2011 – page 10-12). The harvest is expected to increase with a decreasing ratio over the period, i.e. from about 108 to 105% compared to the average of the reference period.

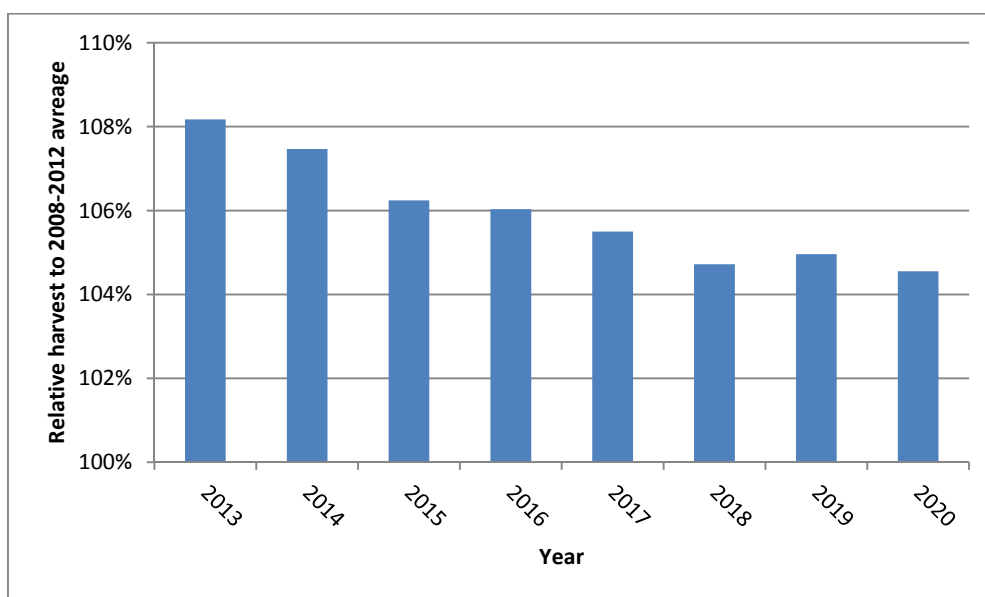


Figure 20. The projected harvest for the second commitment period relative to the average harvest 2008-2012 for the corrected Forest Management Reference Level.

Using the harvest ratios of Figure 20 the projected inflow to the HWP pool is estimated as shown in Figure 21 using the average total inflow 2008-2012, which was about 122.000 Mg C. The projected inflow is around 130.000 Mg C on average for the period, with a slightly decreasing tendency in accordance with Figure 20. The projected inflow for 2013 is about 12.000 Mg C lower than the reported figure, primarily due to underestimation of the inflow from wood-based panels.

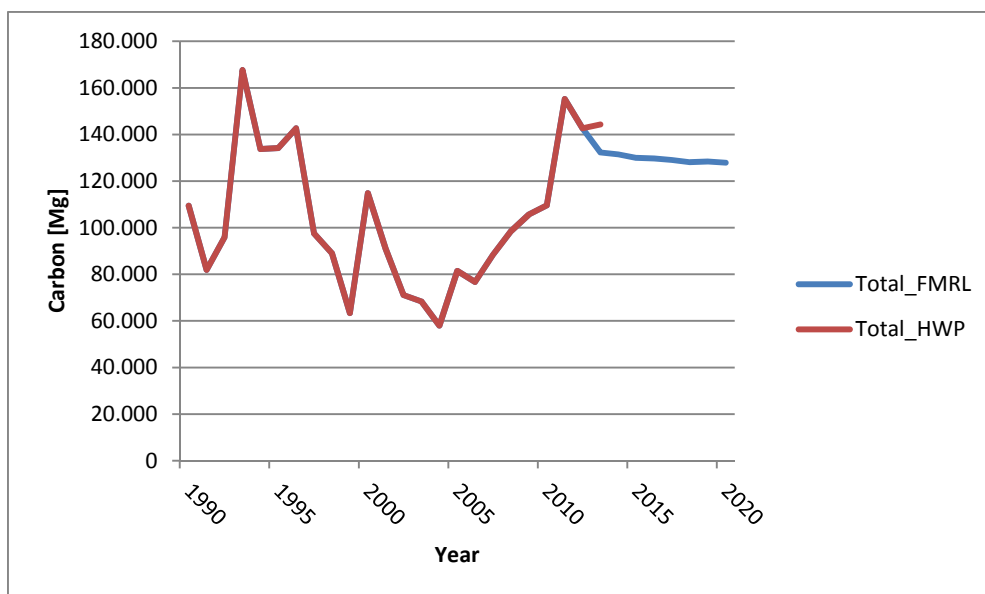


Figure 21. Inflow to the HWP pool from 1990-2013 (Total_HWP) compared with the projected inflow 2013-2020 by the corrected forest management reference level.

Figure 22 shows the change in the HWP pool. The pool is projected to increase through 2013-2020 with a clearly decreasing trend from an increase around 20,000 Mg C at the beginning of the period to around 15,000 Mg C at the end of the period.

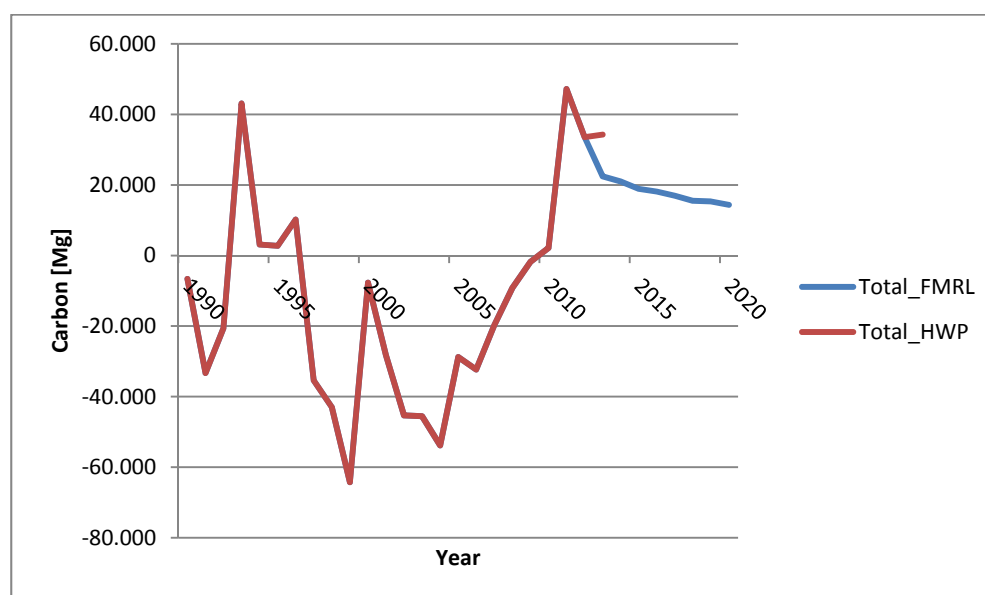


Figure 22. Change in the HWP pool from 1990-2013 (Total_HWP) compared with the projected change 2013-2020 by the corrected Forest management reference level (Total_FMRL).

If the 2005-2009 reference period had been employed with the corrected data, this would have led to a significant underestimation of the inflow and thus the increase of the HWP pool – it would actually show a decrease in the pool (see Figure 23). The reason for this is that the inflow has been increasing over the entire period from 2005-2011, after which it decreases somewhat but remains at a significantly higher level compared to the average of 2005-2009.

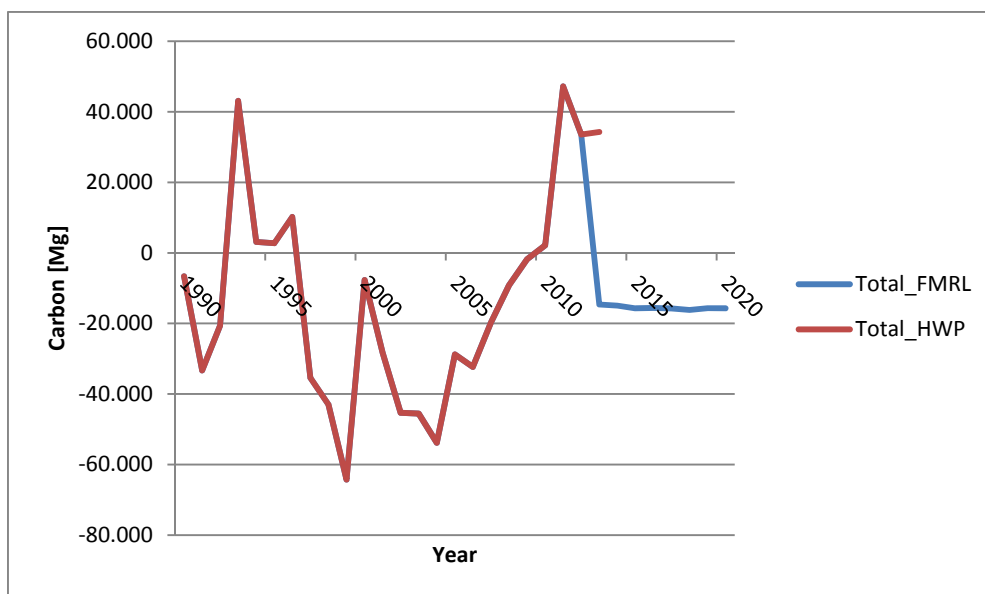


Figure 23. Change in the HWP pool from 1990-2013 (Total_HWP) compared with the projected change 2013-2020 by the corrected FMRL (Total_FMRL) using 2005-2009 as reference period.

In Table 9 the projections of the FMRL for the second commitment period (2013-2020) is shown along with the reported figures for inflow and change of the HWP pool for 2013 in units of kt C and Mt CO₂ eq. (t = metric tons) - according to Figure 21 and Figure 22.

Table 9. Inflow and change for the HWP pool for the second commitment period: Reporting for 2013 and FMRL projections.

Parameter	Year							
	2013	2014	2015	2016	2017	2018	2019	2020
Inflow - Reported [kt C]	144							
Inflow - FMRL [kt C]	132	131	130	130	129	128	128	128
ΔC - Reported [kt C]	34							
ΔC - Reported [Mt CO ₂ eq.]	0,126							
ΔC - FMRL [kt C]	22	21	19	18	17	16	15	14
ΔC - FMRL [Mt CO ₂ eq.]	0,082	0,077	0,069	0,066	0,062	0,057	0,056	0,053

The FMRL thus specifies a HWP contribution for 2013-2020 of a *projected average annual net emission* of:

-0,065 Mt CO₂ eq./year.¹⁵

This figure will be reported to the UNFCCC as *the HWP-contribution* to the Danish FMRL for *Forest Management* for the second commitment period.

Table 10 shows the applied *technical correction* for the FMRL as calculated by 2013 KP Supplement Equation 2.7.1 (cf. Section 2.3.3). The table shows the original values (Decision 2/CMP.7) and the corrected values with and without the HWP contribution, as well as the attached technical corrections. The FMRL

¹⁵ The negative sign reflects that there is a net sequestration of carbon.

excluding HWP has been corrected to 0,364 Mt CO₂ eq./year, i.e. the applied technical correction is 0,030 Mt CO₂ eq./year (see Nielsen et al., 2015). The FMRL including HWP is corrected to 0,299 Mt CO₂ eq./year resulting in a total technical correction of ÷0,110 Mt CO₂ eq./year, where ÷0,140 Mt CO₂ eq./year arises from the HWP contribution.

Table 10. Technical correction applied to the FMRL with and without the HWP contribution.

Net-emissions, 2013-2020 [Mt CO₂ eq./year]	FMRL	FMRL - applying FOD function for HWP
Decision 2/CMP.7	0,334	0,409
Corrected value	0,364	0,299
<i>Technical correction</i>	<i>0,030</i>	<i>-0,110</i>

According to Table 10 the HWP contribution to the original FMRL was 0,075 Mt CO₂ eq./year (0,409÷0,334 Mt CO₂ eq./year) - i.e. the original FMRL projects a decrease of the HWP pool, while the corrected FMRL projects an increase of the pool. In addition to the shift in reference period, this change is caused by the correction of activity data and the exclusion of exported HWP. Whereas the original FMRL was based on HWP from domestic harvest only, the corrected FMRL is based on HWP domestically produced and consumed.

The effect of excluding exported HWP is a decrease in the stock, as well as a decrease in the inflow to the pool. As the export has been decreasing in recent years, according to the corrected data (see Figure 10 and Figure 11), the net effect of this is that the loss from the pool (inherited emissions) is decreased more (due to a lower stock) than is the inflow – compared to the pool of HWP from domestic harvest only. Furthermore the correction of inflow data has also decreased the historic inflow, resulting in a lower stock as seen in Figure 17. This also lowers the loss from the pool. In addition the correction has increased the inflow in recent years. All in all these changes result in a negative level of net emissions in the second commitment period for the HWP pool, instead of a positive level.

3.3 Wood flows

For the year of 2012 the collective wood flows in Denmark has been mapped as a part of cross validating the sources of data used in the HWP reporting. In this regard data from the Danish Energy Agency has been applied to account for the use of wood in the energy production in Denmark, including the use of firewood in private homes. The source is independent of Statistics Denmark inventories on the production of timber and fuelwood.

In respect to this reporting it is noted, cf. Section 3.1, that the production and export of timber as estimated by Statistics Denmark tallies with the consumption of roundwood reported by the wood industry. However the amount of imported roundwood reported by Statistics Denmark is not in accordance with the apparent consumption. Furthermore there is a quite large discrepancy between the size of the production of firewood from the forests reported by Statistics Denmark and the total consumption of firewood reported by the Danish Energy Agency. The production is reported to about 500.000 m³, and the consumption to about 2,1 Mio. m³ - leaving 1,6 Mio. m³. That there is a substantial production outside the forests is very likely, and this should explain a large part of the discrepancy. However no direct estimates of

the size of this production exist. The estimation of the firewood consumption by the Danish Energy Agency is based on a questionnaire employing a sample of all the consumers of firewood (Evald, 2013). As Statistics Denmark figures are supported by NFI estimates regarding the total harvest in the Danish forests, it suggests that the missing volume cannot be explained by underestimation of the harvest from the forests.

It is important to note that the harvest estimations of Statistics Denmark and the NFI is methodologically different as the former is based on a questionnaire, while the latter is based on plot sampling of the forest area. As for the NFI the number of available sampling units for the harvest estimation will increase in the coming years, reducing the uncertainty accordingly (Johannsen et al., 2013 – page 74) – and thus providing an even more precise estimate of the harvest.

The mapping of the wood flows is still ongoing and efforts will be made to explain the disagreements. Regarding the HWP reporting it is the current assessment that the disagreements will not have a significant impact on the estimations of inflow to the HWP pool. In all likelihood the disagreement on firewood is internal to the energy part of the flows, and will not concern the production of HWP. The further analysis of the overall wood flow will contribute to clarification of these topics.

3.4 Uncertainty

This section provides an overview on the uncertainties related to the results of this reporting. The uncertainty related to the choice of SFWP to account for the HWP contribution to the overall carbon stock will not be discussed.

3.4.1 Uncertainty on methods

Uncertainty on methods relates to the choice of model to describe the development of the HWP pool over time. When applying the Tier 2 flux method a FOD function is used. According to the 2013 KP supplement it is “assumed to be a good proxy for the decay of semi-finished wood products” (IPCC, 2014 – page 2.132). However, the behaviour of the HWP pool may possibly also follow another other type of decay function. Pingoud et al. (2001) use a logistic model, when analysing the development of the HWP pool in Finland (see also Pingoud & Wagner, 2006). For Denmark there is no evidence to suggest which function to use, i.e. the Tier 2 method was applied. Ultimately the size of the stock is determined by the size of the inflow and the expected life time of HWP.

3.4.2 Uncertainty on parameters

The 2006 IPCC Guidelines indicates an uncertainty of about +/- 50% on the default half-life parameter (IPCC, 2006 – page 12.22). The influence of the uncertainty on half-life is assessed by a sensitivity analysis regarding the outflow from the HWP pool. Figure 24 show the sensitivity of the estimated 2013-outflow for sawnwood and wood-based panels to the choice of half-life. For sawnwood the estimation is relative insensitive to the variation in half-life. The outflow is peaks at a half-life = 30 years. Only when the half-life falls below 15 years, there is a significant change in the outflow. This is also seen in Table 11 - a variation of +/- 50% in half-life only results in a reduction of 4% compared to the default value of 35 years. For wood-based panels the sensitivity is larger, with the outflow decreasing continuously with increasing half-life, thus a +/- 50% variation in half-life results in a +23%/-17% change in outflow.

The reason for this difference in sensitive is the characteristics of the sub pools. The pool of sawnwood is relatively large compared to the resent inflow, whereas the opposite is true for the pool of wood-based

panels, cf. Figure 14 and Figure 18. As to the former, a change in half-life will have a limited effect, because the change in retention of recent inflow will be balanced by the change in emissions caused by the change in the historic pool. In the case of the latter the change in retention of recent inflow outweighs the change in the historic pool.

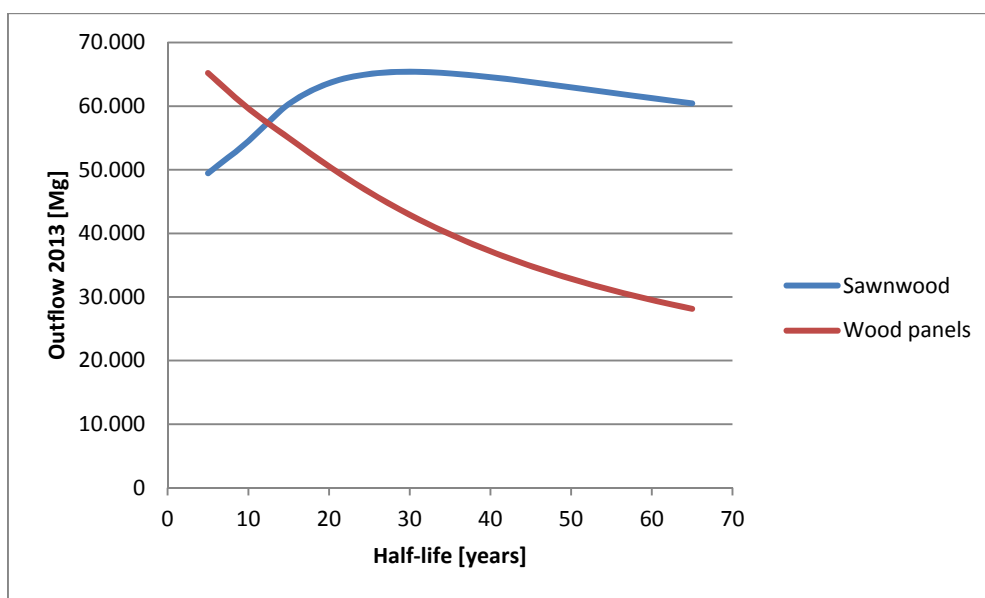


Figure 24. Sensitivity on half-life: the estimated carbon outflow as a function of half-life.

Table 11. Relative outflow – 2013, when varying default half-lives of sawnwood (35 years) and wood-based panels (25 years) +/- 50 %.

Category	Half-life - relative		
	-50%	Default	+50%
<i>Sawnwood</i>	96%	100%	96%
<i>Wood panels</i>	123%	100%	83%

3.4.3 Uncertainty on activity data

According to the 2013 KP Supplement (IPCC, 2014 – page 2.133) uncertainty on activity data is caused by:

- Length of time series for activity data
- Uncertainty on definitions
- Limited resources for data collection
- Reporting errors
- Missing subcategories

These points in general refer to some form of measurement uncertainty. In addition statistical uncertainty may also be included if data acquisition is based on statistical sampling. According to the expert judgment

of authors of the 2013 KP Supplement uncertainty on the reported values on inflow may lie between +5% and -25%, i.e. that under-reporting is likely. In the Danish case regarding data from Statistics Denmark and FAO-STAT the relevant uncertainty pertains to the reporting of roundwood and the following conversion to sawnwood. Errors on reporting and limitations on data collection are probably the most important factors, as well as statistical uncertainty on the estimation of the annual harvest. Regarding the Questionnaire uncertainty pertains to the companies' ability to report correct volumes and the overall coverage of the wood industry. This uncertainty appears to be limited according to the cross-validation on roundwood consumption and the results on the coverage.

Regarding the default conversion factors the 2006 IPCC Guidelines indicates an uncertainty of about +/- 25% on the conversion from volume to biomass and about +/- 10% on the conversion from biomass to carbon. For Denmark it must be expected that uncertainty is decreased somewhat due the application of NFI data and the weighting of the conversion factors by species shares in the production.

3.4.4 Potentials for reducing uncertainty

According to Pingoud et al. (2001 – page 92) applying methods corresponding to 2013 KP Supplement Tier 2 are “highly uncertain”. They suggest that inventories of the carbon stock, with focus on the expected major pools as, e.g., wood used for construction, can be applied to validate the choice of model and parameters. Such an inventory is dependent on an extensive database on wood use. For Finland, Pingoud et al. (2001) expects that the majority of carbon is stored in buildings and major construction works. This is probably also the case for Denmark. For this reporting the estimation of the carbon stock by inventory has not been attempted.

Skog et al. (2004) have analysed the contribution of the individual variables to the overall uncertainty when estimating HWP pool changes – i.e. they analyse uncertainty on parameters and activity data but not uncertainty on method. They find that uncertainty on recent data and carbon conversion factors are the highest contributors to the overall uncertainty, as may be expected. Uncertainty on half-life has a small contribution, but as is shown in Section 3.4.2 this depend on the development of the pool.

Regarding Denmark, assessments will possibly be made as to the availability of data for conducting inventories of the carbon stock. On activity data, it is the expectation that uncertainty will be reduced continuously, as the continuous gathering of production data by questionnaire will provide more accurate estimates of the most recent inflow, which has the highest impact on stock estimates and thus the uncertainty.

4 Discussion and conclusions

The inflow in 2013 is reported to about 144.000 ton carbon distributed to 63.000 ton carbon from the production of sawnwood and 81.000 ton carbon from the production of wood-based panels. The inflow from the production of paper and paperboards is insignificant. The outflow from the pool is reported to about 110.000 ton carbon in 2013 distributed to 65.000 ton carbon from sawnwood and 45.000 ton carbon from wood-based panels. This means that the net carbon sequestration in HWP was about 34.000 ton carbon in 2013 divided into a net emission of 3.000 ton carbon from sawnwood and a net sequestration of 37.000 ton carbon from wood-based panels.

The corrected FMRL has projected the inflow in 2013 to 132.000 ton carbon distributed to 61.000 ton carbon from sawnwood and 71.000 ton carbon from wood-based panels and the outflow to about 110.000 ton carbon in 2013 distributed to 65.000 ton carbon from sawnwood and 45.000 ton carbon from wood-based panels. Thus the projected net sequestration was about 22.000 ton carbon.

As expected the reported net carbon sequestration is relatively close to the corrected FMRL – as it should be, as there could not be identified any reason why, major changes should have taken place in this short period of time.

Forecasting, *ceteris paribus*, gives the most accurate results, when the baseline of the forecasting uses the most recent data. This will of course depend on the occurrence of years with anomalies and the shift in trends – i.e. the reference period must to the largest extent possible represent the expected future.

This is the primary reason for, why it was decided to use 2008-2012 as the reference period for the corrected FMRL. Another reason is that confidence in the 2008-2012 inflow data is higher compared to the 2005-2009 period, as inflow data from 2011 and 2012 is derived from the Questionnaire on the production of the Danish wood industry and thus data for these two years are the most precise inflow estimates in the considered period of time. Therefore it was discussed only to use those two years as base period, but in due consideration of the guidelines in the 2013 KP Supplement, it was decided also to include the corrected data from 2008-2010 in the base period.

If 2005-2009 had been used as the reference period in the corrected FMRL, it would have lowered the expected inflow in the reporting period and caused a significant gap between the net emissions of carbon reported for 2013 compared to the projection of the FMRL. Thus the HWP pool would actually have been projected to decrease as opposed to the expected increase in the pool providing Denmark with carbon credits, which could not be justified by real changes.

Surveying the production of the Danish wood industry by the use of a questionnaire has been successful judging from the participation and the validation results. It will be repeated in the following years. In this respect it is important to maintain the support of the sector. Besides giving a better basis for the reporting to the IPCC/UNFCCC the questionnaires provides a valuable insight into the wood industry and in the wood flow in general. The general results from the project will therefore be published widely.

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